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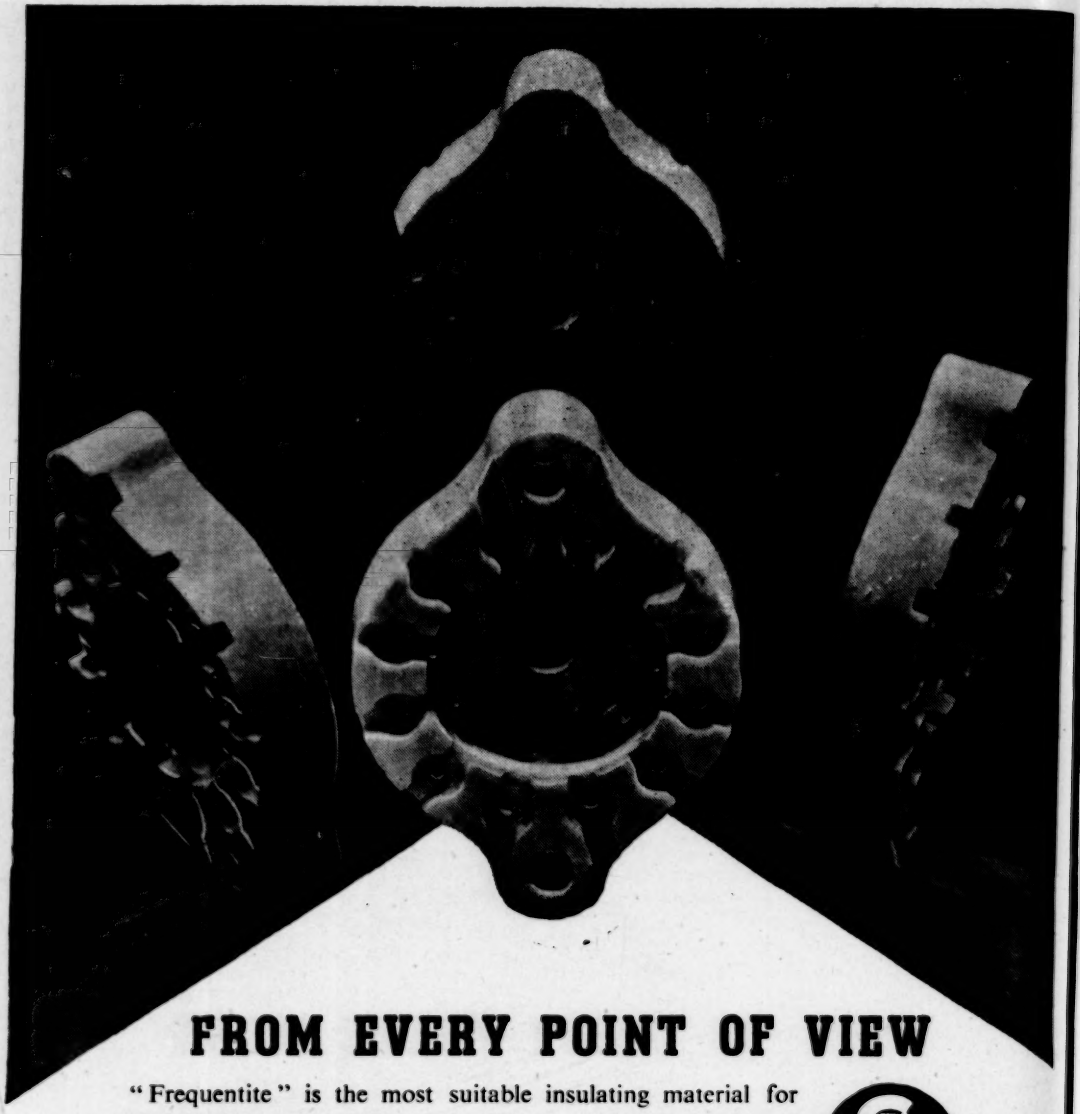

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WIRELESS ENGINEER

Editor HUGH S. POCOCK, M.I.E.E. Technical Editor Prof. G. W. O. HOWE, D.Sc., M.I.E.E.

VOL. XXII MARCH, 1945 No. 258

EDITORIAL

The Pinch Effect: An Electrostatic Phenomenon

WHEN an electric current passes through a trough containing molten metal, the force exerted on the external portions, due to the fact that they are carrying current in a magnetic field, causes a contraction of the cross-section, and a waist may be produced which may decrease in diameter with resulting increasing current density and increasing magnetic field strength until the continuity of the liquid is actually broken. This phenomenon is known as the pinch effect and is a cause of trouble in some types of electric furnace. A question which has recently been propounded to us is whether in a solid conductor there is any tendency for the current to concentrate towards the inner parts of the conductor, or in other words, whether the current experiences any pinch effect, and if not, why not ?

Assuming the conductor to be of copper the number of atoms per cubic centimetre is about 84×10^{21}; there appears to be some uncertainty about the number of free electrons but it will be sufficient for our purpose to assume one free electron per atom. If the mass of an atom of hydrogen is 1.67×10^{-24} gram, that of an atom of copper will be $63.6 \times 1.67 \times 10^{-24}$ gram. The mass of one cubic centimetre of copper being 8.9 grams, the number of atoms in the cubic centimetre is thus about 84×10^{21}. The charge of an electron is about 4.8×10^{-10} e.s. unit or 1.6×10^{-19} coulomb. If the average drift velocity of the electrons in the direction of the current flow is v cm/sec. the current density in amperes per square centimetre will be $(84 \times 10^{21}) \times (1.6 \times 10^{-19}) \times v$. For a current density of 10,000 amperes/cm^2 the drift velocity $v = 0.75$ cm/sec.

Most people are surprised to learn that the velocity of the electrons which constitute the electric current in a copper wire is only of the order of a few millimetres per second even for relatively high current densities, but this has to be taken in conjunction with the fact that there are 84×10^{21} of them in every cubic centimetre.

The Radial Force on an Electron

Let us now consider a copper wire 1 cm diameter carrying a current of 10 000 amperes. At its surface the magnetic field $H = 2I/10r = 4000$ and the drift velocity at this current density will be about 1 cm/sec. The force on an electron near the surface due to its movement in the magnetic field will be $qvH/10$ that is $(1.6 \times 10^{-20}) \times 1.0 \times 4000 = 6.4 \times 10^{-17}$ dynes. Here again, although this appears infinitesimal, when multiplied by the number of electrons in the cubic centimetre it gives a force of $(6.4 \times 10^{-17}) \times (84 \times 10^{21})$ dynes or 12 lb. per cubic centimetre near the surface. The force on the electrons throughout the mass, being proportional to H, is proportional to the distance from the centre.

The inward force on an electron at radius x is $12.8\ x \times 10^{-17}$ dyne. In a solid conductor this force will certainly cause a radial drift of the electrons towards the centre, but what is the magnitude of the effect? A copper conductor 1 cm diameter has a resistance per cm of 2.16 microhms, and when carrying a current of 10 000 amperes the voltage drop will be 2.16×10^{-2} V/cm, which, divided by 300 gives the electric force $\mathcal{E}$ as 0.72×10^{-4} e.s. units. The axial force on the electron is thus $(4.8 \times 10^{-10}) \times (0.72 \times 10^{-4}) = 3.46 \times 10^{-14}$ dynes, which is about 500 times the greatest radial force. The radial drift would thus be very slow, but, as soon as it begins, it creates a force that stops it, for any concentration of electrons towards the centre would set up a radial electric field tending to force the electrons radially outwards. Assuming that, as the result of the inward radial drift of free electrons, there is an excess of n electrons per cubic centimetre, the charge per cm of length inside a radius x will be $n \times \pi x^2 \times 4.8 \times 10^{-10}$ e.s. units which will produce at the radius x an electric field strength $\mathcal{E}$ equal to $2/x$ of this charge, that is about $30nx \times 10^{-10}$. The resulting outward force on an electron at this radius will be $(30\ nx \times 10^{-10}) \times (4.8 \times 10^{-10}) = 144\ nx \times 10^{-20}$ dyne. For the outward and inward radial forces to balance n must increase until $144\ nx \times 10^{-20} = 12.8\ x \times 10^{-17}$ which gives about 90 excess electrons per cm^3. In view of the enormous number of free electrons in each cubic centimetre this excess is entirely negligible.

The Real Nature of the Pinch Effect

It is thus seen that the electrodynamic forces on the axially moving electrons cause a radial drift towards the centre, but that a microscopic movement in this direction is sufficient to set up a radial electrostatic field sufficient to counterbalance the radial force on the electrons, which therefore pursue their purely axial drift. If this be a correct picture of what occurs in either a solid or a liquid conductor, where are we to look for the cause of the pinch effect in the case of the liquid? Surely to the action of the radial electrostatic field on the atoms which, having provided the free electrons, are themselves positively charged. The force will be towards the centre and in this case there is no counterbalancing electrodynamic force. This force on the atom is proportional to its distance from the centre and to the square of the current density, since it must be equal to the force on the electron and

$$qvH/10 = (q/10)(I/\pi r^2 nq)(2Ix/10r^2) = \frac{2I^2x}{100\ \pi n r^4}$$

At the surface of a column of changing radius the force is inversely proportional to the cube of the radius, whilst at its centre the hydrostatic pressure is inversely proportional to the square of the radius, so that, if a waist forms, the forces tending to accentuate it increase rapidly as the radius decreases.

Hence, although the *fons et origo* of the effect is the electrodynamic force on the electrons, the actual pinch phenomenon is caused by purely electrostatic forces.

The same applies to all cases in which a force is exerted upon a conductor due to it carrying a current in a magnetic field. When current flows in the armature conductor of a motor it is the moving free electrons that experience a tangential force, and they consequently tend to drift towards one side of the conductor. As in the pinch effect, however, the slightest departure from uniformity of distribution sets up electrostatic forces between the electrons and the positively charged atoms, thus transmitting the tangential force to the latter.

G. W. O. H.

Abstracts Index

THE subject and author index to the 4 000 abstracts and references published in *Wireless Engineer* during 1944 is now ready. It occupies 40 pages and costs 2s. 8d., including postage. Early application should be made to our Publisher for copies, as supplies are limited.

LAW LINEARITY OF SEMI-CIRCULAR PLATE VARIABLE CONDENSERS*

By W. H. F. Griffiths, F.Inst.P., M.I.E.E., S.M.I.R.E.

SUMMARY.—When used primarily as standards of capacitance variable condensers having linear laws of capacitance are preferable to those having linear frequency laws. The law imperfection caused by the peripheral edge capacitance in variable condensers of the latter type are absent in the former, but appreciable imperfection of the same kind may be introduced by eccentricity of moving and fixed plates relative to the axis of rotation. Formulae are developed for the law errors due to this cause, and for the inaccuracy of interpolation introduced by such errors.

The linearity of law is impaired also by the edge capacitance of the leading and trailing radial edges of the moving plates. That of the latter is the more important and this is dealt with quantitatively, formulae being developed by an approximate method both for law error and for the correction of the shape of moving plate which will sensibly eliminate such error.

There are further causes of law imperfection which, unlike the foregoing, are a function of frequency. These are the constant and variable components of the residual self-inductance of the variable condenser. Formulae are developed for the effects of these upon the law of a condenser and for the inaccuracies attending such effects.

Finally, formulae are developed for the design of a variable condenser to have a perfectly linear law of capacitance at any given high frequency even though that frequency is sufficiently high to produce frequency corrections of considerable magnitude.

THE variable air condensers used in radio and communication engineering are almost invariably of the linear frequency scale type designed to have an inverse square law of capacitance. In a recent article† in this journal the present author has shown the difficulties which attend the design of such condensers. Unless precautions are taken, the perfection of frequency law is limited by various causes of error some of which are due to the construction of the condenser and others to the design of the associated circuit. At frequencies up to, say, 1 Mc/s the principal *law* errors‡ of the condenser itself are those which are introduced by the effects of edge capacitance of both the shaped peripheral edges of the conventional moving plates and their radial leading and trailing edges. Of these the peripheral edge capacitance has the more general effect upon the law since it operates throughout the entire range of the condenser. This effect upon the law is calculable, and formulae were developed for it in the article referred to previously.

When a variable condenser is to be used as a general standard of capacitance rather than as a calibrated means of adjusting a circuit to resonance, a linear law of frequency is not suitable and the simpler type having semi-circular moving plates is therefore substituted. This is so, even if the condenser is to be used at high frequencies, because of the simplicity and accuracy with which interpolation can then be effected between adjacent calibrated capacitances. Because of the geometrical simplicity of a variable condenser having a linear capacitance law there would appear to be little chance of law imperfection. This is far from being the case however. It is true that one of the principal defects—that due to the peripheral edge capacitance of the moving plates—is eliminated by the simplification of law, but those caused by radial edge capacitance, non-equality of dielectric air gaps§, and moving plate "wobble," remain. There remain also two constructional defects which may influence the law of a linear capacitance variable condenser —those of eccentricity, either of the peripheries of the moving plates relative to their axis of rotation, or of the inner semi-circular edges of the fixed plates relative to the same axis.

* MS. accepted by the Editor, November, 1944.

† "Direct Reading of Frequency of Resonant Circuits," *Wireless Engineer*, Nov. and Dec., 1943.

‡ Even at frequencies lower than 1 Mc/s, however, it is necessary to apply frequency corrections to the low frequency capacitance calibration of a variable condenser, as will be seen later.

§ The effect of plate wobble together with its accompanying defect, inequality of dielectric air gaps, has also been dealt with by the present author. *loc. cit.*

The effects upon the linearity of law of these two defects are readily calculable, but before proceeding with their investigation a brief note will be given on the dimensions of the scale, and *their* effect upon the accuracy of interpolation. Obviously, inadequacy of dimensions of the scale may impose a limit to the accuracy of interpolation even though the law be perfect.

The linear law condenser is provided with a scale divided directly in terms of capacitance, or with one graduated in degrees of arc, or some other arbitrary linear subdivision. In either case the condenser is standardised with accuracy at a number of capacitances. Preferably these capacitances should be of cardinal values so that there is provided a number of fixed cardinal capacitances the accuracies of which are limited only by the accuracy of setting two lines to coincidence, by the accuracy of the original calibration, and, at any time subsequently, by the ageing of the condenser. The accuracy of setting two lines to coincidence depends, of course, upon the fineness of division lines, but the accuracy with which the angular position of the moving system of the condenser may be observed and reproduced depends also upon the radius at which these lines are engraved.

The scale dimensions and quality of dividing govern to an even greater extent, however, the reading of any capacitance other than those calibrated. For these capacitances the scale inaccuracy may be expressed as the smallest circumferential distance to which consistent readings may be made. For the reading of an accurate degree scale with the assistance of an accurately matched vernier, this distance is 0.01 cm. in the author's opinion. In the case of a scale divided directly in terms of capacitance, however, he feels that the distance should be more conservatively stated as 0.03 cm, because no assistance is available from a vernier.

If, therefore, we express the circumferential distance of 0.01 cm as an angle $\delta\theta$

$$\delta\theta = \frac{0.01 \text{ Radian}}{R_s} = \frac{0.01 \times 180}{\pi R_s} = \frac{0.573}{R_s}$$

where R_s is the radius of the scale.

The scale inaccuracy $\eta = \delta\theta \cdot \left|\frac{dC}{d\theta}\right| mC$

where m is the degree (diameters) of any magnification provided to facilitate scale reading.

Expressed as a percentage this becomes

$$\eta = \frac{57.3}{mR_s} \cdot \frac{1}{C} \cdot \frac{dC}{d\theta} \quad .. \quad .. \quad .. \quad (1)$$

where $\frac{dC}{d\theta}$ is obviously $\frac{C_{max.} - C_{min.}}{160}$ it being assumed that the condenser law is approximately linear from $\theta = 10$ deg. to $\theta = 170$ deg. and that the capacitances corresponding to these two angles are termed $C_{min.}$ and $C_{max.}$ respectively. The greatest scale inaccuracy is

$$\eta_{max.} = \frac{57.3}{mR_s} \cdot \frac{1}{C_{min.}} \cdot \frac{dC}{d\theta}$$

and if the overall inaccuracy of an interpolated capacitance permissible is α,

$$\text{then } \eta \leqslant \frac{\alpha}{3}$$

and therefore

$$R_s \geqslant \frac{172}{m\alpha} \cdot \frac{1}{C_{min.}} \cdot \frac{dC}{d\theta} \quad .. \quad .. \quad (2)$$

In Fig. 1 the heavily drawn semi-circles represent the peripheral edges of the moving plates and the inner edges of the fixed plates. These edges are eccentric by amounts x and y respectively from the true chain dotted semi-circles which are described from the axis of rotation.

The maximum amounts of eccentricity x and y occur at angles γ and τ from $\theta = 0$ respectively. Although these angles will, in practice, *most probably* be different, the angles $\gamma + \phi$ and $\tau + \beta$ *must* always be equal for any given angular condenser setting θ. In Fig. 1 these compound angles have been shown different for clarity of drawing only. The radii R_t and r_t are those of the true semi-circles described from the axis, o, of rotation, while R_m and r are the radii of the moving and fixed plate edges described from the points M and F respectively.

If x and y are small distances

$$\delta R_t = x \cos\phi \quad \text{and} \quad \delta r_t = y \cos\beta$$

$$R_m = R_t + \delta R_t = R_t + x\cos\phi$$

$$r = r_t + \delta r_t = r_t + y\cos\beta$$

and $\frac{dA}{d\theta} = \frac{1}{2}(R_m^2 - r^2)$

therefore

$$\frac{dC}{d\theta} = \tfrac{1}{2}k(R_m^2 - r^2)$$

where k is a constant for the conversion of plate area into condenser capacitance.

$$k = 0.716 \frac{C_{max.} - C_{min.}}{R_m^2 - r^2}$$

Remembering that $\phi = \theta - \gamma$ and $\beta = \theta - \tau$

$$\frac{dC}{d\theta} = \tfrac{1}{2}k\left[\{R_t + x\cos(\theta-\gamma)\}^2 - \{r_t + y\cos(\theta-\tau)\}^2\right] \quad (3)$$

$$= \tfrac{1}{2}k\{R_t^2 + 2R_t x\cos\phi + x^2\cos^2\phi + r_t^2 - 2r_t y\cos\beta - y^2\cos^2\beta\}$$

$$\frac{d^2C}{d\theta^2} = \tfrac{1}{2}k\{-2R_t x\sin\phi - x^2\sin 2\phi + 2r_t y\sin\beta + y^2\sin 2\beta\}$$

ignoring the terms containing the squares of the already small quantities x and y this expression simplifies to :—

$$\frac{d^2C}{d\theta^2} = k\{r_t y\sin(\theta-\tau) - R_t x\sin(\theta-\gamma)\} \quad (4)$$

The $dC/d\theta$ curve will be practically straight between adjacent calibrated points whatever the cause of the imperfection of law.* Thus the two calibrated points A and B of Fig. 2 may be regarded as being joined by a portion of the $dC/d\theta$ curve which is sensibly a straight line. Having by calibration determined the angular scale settings θ_A and θ_B for the adjacent cardinal capacitances at A and B respectively, interpolation between them is then effected on the assumption of a linear law having a value of $dC/d\theta$ equivalent to that at the point X exactly midway between A and B.

Let the number of equidistant calibrated points throughout the range 10 to 170 degrees be N, then the capacitance of X is read, incorrectly, as

$$C_X = C_A + \left\{\frac{80}{N-1}\cdot\frac{dC}{d\theta}\text{ at }\theta_X\right\}$$

$$= C_A + \left\{\frac{80}{N-1}\left(\frac{dC}{d\theta}\text{ at }\theta_A + \frac{80}{N-1}\cdot\frac{d^2C}{d\theta^2}\right)\right\}$$

The correct capacitance at X is, however,

$$C_X = C_A + \left\{\frac{80}{N-1}\left(\frac{dC}{d\theta}\text{ at }\theta_A + \frac{40}{N-1}\cdot\frac{d^2C}{d\theta^2}\right)\right\}$$

The maximum interpolation error caused by an inconstant value of $dC/d\theta$ occurs at a point exactly midway between adjacent calibrated capacitances and this, as is seen above, is given by

$$+\frac{3200}{(N-1)^2}\cdot\frac{d^2C}{d\theta^2} \quad (5)$$

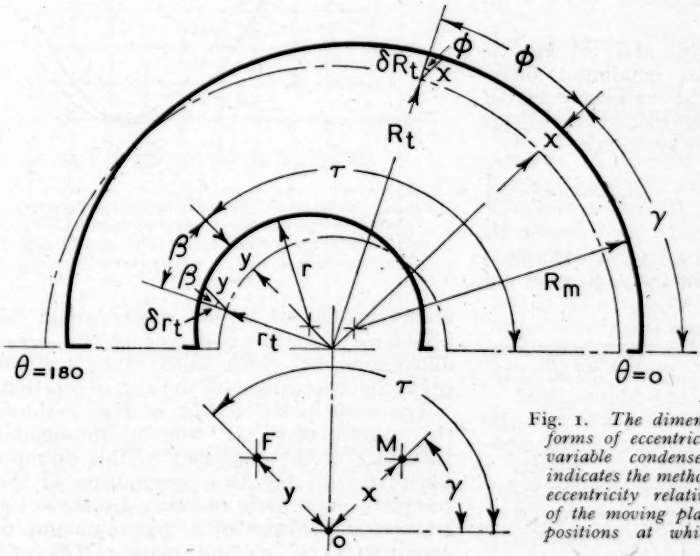


Fig. 1. *The dimensioning of the two possible forms of eccentricity of a semi-circular plate variable condenser. The smaller drawing indicates the method of defining the amounts of eccentricity relative to the axis of rotation of the moving plate system, and the angular positions at which they occur relative to* $\theta = 0$.

The error will be found to be the same both in magnitude and algebraic sign if C_X is computed from C_B.

It will be appreciated that a standard condenser has many sources of error other than that of non-linearity of law. There are even several sources of non-linearity of law. Any one of these sources of error cannot be

* Excluding, of course, local imperfections which may be caused by irregularities in the construction of the variable condenser. Such imperfections are negligible in a condenser of the best quality however.

allowed to approach the total inaccuracy which has been termed α. The maximum error due to interpolation therefore should,

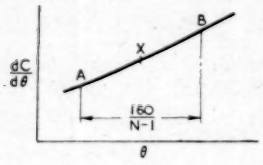


Fig. 2.

at least, be limited to $\alpha/5$ for any one cause of law imperfection.

Then $$\frac{3200}{(N-1)^2}\cdot\frac{d^2C}{d\theta^2}\Big/C \leqslant \frac{\alpha}{5}$$

when the value of $\frac{d^2C}{d\theta^2}\Big/C$ has a maximum value, from which it is seen that the angle between adjacent calibrated points at various parts of the scale must not exceed

$$\frac{160}{\sqrt{\frac{15\,600}{\alpha C}\cdot\frac{d^2C}{d\theta^2}}} \qquad .. \quad .. \quad .. \quad (6)$$

Applying expressions (5) and (6) to the present problem: The maximum interpolation error caused at various parts of the scale by the combined eccentricity effects of moving and fixed plate systems is

$$\frac{k}{(N-1)^2}\left\{ry\sin(\theta-\tau)-R_m x\sin(\theta-\gamma)\right\} \qquad .. \quad .. \quad (7)$$

and the angle between adjacent calibrated points at various parts of the scale must not exceed

$$\frac{160}{\sqrt{\frac{5k}{\alpha}\cdot\frac{ry\sin(\theta-\tau)-R_m x\sin(\theta-\gamma)}{C}}} \qquad .. \quad .. \quad (8)$$

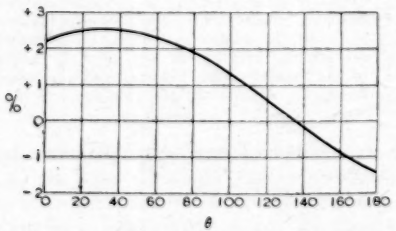


Fig. 3. *The percentage deviation of the law of a variable condenser from linearity caused by a combination of the eccentricities of moving and fixed plates. The curve is computed using formula* (3).

As an example the case depicted in Fig. 1 is taken with the following numerical values:

$R_m = 10$ cm $\quad x = 0.1 \quad \gamma = 45$ deg.
$r = 2$ cm $\quad y = 0.1 \quad \tau = 135$ deg.
$k = 10$
$\alpha = 0.0001$

For this example the curve of Fig. 3 has been plotted using expression (3) to show the deviation of the law from linearity caused by the combination of the eccentricities of moving and fixed plates. The deviation is shown as a percentage change from the

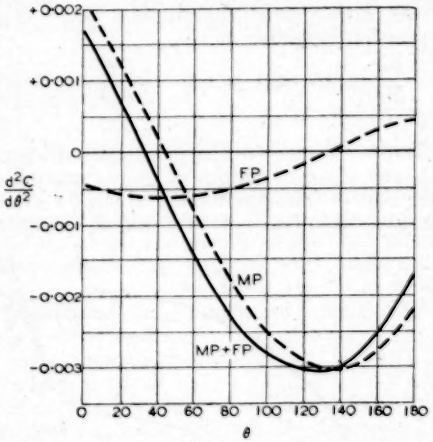


Fig. 4. *Showing $d^2C/d\theta^2$ of a variable condenser, caused by eccentricity of moving plates (MP), by eccentricity of fixed plates (FP) and by both causes (MP + FP). Computations using formula* (4).

normal value of $dC/d\theta$ which would be associated with a condenser of the same dimensions but with both plate systems perfectly concentric with the axis of rotation.

The curve $(MP + FP)$ of Fig. 4 shows the variation of $d^2C/d\theta^2$, from (4), throughout the range of the condenser of this example together with the two components of the complete expression in order to show the relative importance of a given amount of eccentricity on moving-plates (MP) and fixed plates (FP).

For the same example the curves of Fig. 5 show the interpolation errors to be expected at various parts of the scale when $N = 8$ and the greatest angular distances permissible between the calibrated capacitances for an accuracy of 1 part in 10^4

It is obvious that the latter curve must be interpreted reasonably. For example,

at $\theta = 40$ the angular interval permissible between adjacent calibrated points is read from the curve as approximately 40 degrees. Actually, however, this cannot be realised because such a large interval would embrace also a portion of the curve which reads only 25 degrees. Thus the curve must be interpreted as indicating intervals of little more than 20 degrees throughout the range of the condenser, except possibly at the highest capacitance end of the scale where the intervals may be increased to 25 degrees or even to 30 degrees. In practice these angular intervals may be limited still further by another consideration. It is preferable that the capacitances calibrated should be of cardinal values and this will usually mean a still further reduction of the dimensions of *all* intervals to an angle lower than a *reasonable* minimum of the curve between $\theta = 10$ and $\theta = 170$.

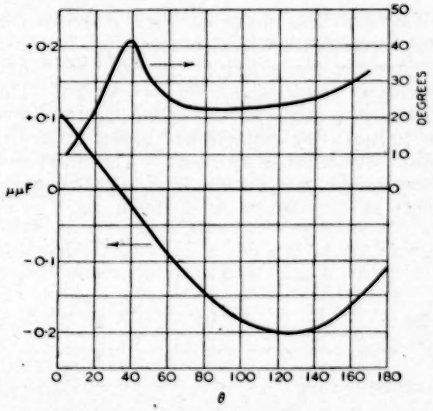


Fig. 5. *Showing the maximum interpolation inaccuracy (in $\mu\mu F$) which occurs when eight equidistant capacitances are calibrated and, alternatively, the greatest angular intervals which are permissible at various parts of the scale if the inaccuracy of interpolated capacitances is not to exceed* 0.01 *per cent. These curves result from the values of $d^2C/d\theta^2$ shown in Fig.* 4 *and were plotted using formulae* (7) *and* (8).

It is unnecessary to calculate a plate-shape correction to compensate for these law inaccuracies because they are caused by errors of workmanship rather than of design. Obviously, the best method of correction is to reassemble the condenser correctly.

There is another geometrical source of law imperfection which is common to variable condensers of all laws—the edge capacitance between the trailing radial edges of the moving plates and the radial edges of the fixed plates which they are just leaving as the capacitance of the variable condenser is

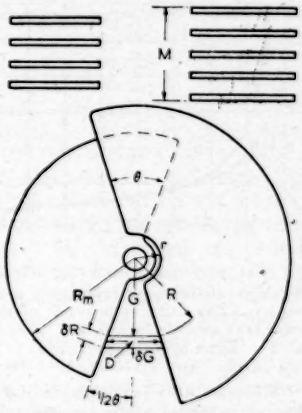


Fig. 6. *The dimensioning of the electrostatic field from the trailing radial edges of the moving plates of a variable condenser.*

being increased from the minimum capacitance at $\theta = 0$. Unlike that considered previously this law error is not caused by an error of workmanship but rather by design and so a plate-shape correction may be applied. The error is, of course, very great from $\theta = 0$ to, say, $\theta = 10$ degrees and diminishes rapidly as the capacitance is increased; it may be appreciable, however, up to $\theta = 30$ or even 40 degrees and so must be calculated and if possible corrected at least above $\theta = 10$ degrees* in order to obtain the best possible interpolation accuracy from $\theta = 10$ degrees to $\theta = 170$ degrees.

The author has found the following approximate method very useful for estimating the law imperfection caused by the "trailing edge capacitance" effect. It is based upon the assumption that the capacitance between the radial edges of moving and fixed plates is the same as that between two completely plane radial surfaces. This assumption is erroneous from $\theta = 0$ to $\theta = 10$ degrees and the estimated law error may be excessive even at $\theta = 15$ degrees if the dielectric gaps are large compared

* In a variable air condenser of high accuracy the range of accurately standardised capacitance is usually regarded as that from $\theta = 10$ degrees to $\theta = 170$ degrees.

with the thickness of the plates. From this latter angle the approximate treatment which follows holds extraordinarily well however. Moreover, the correction applied

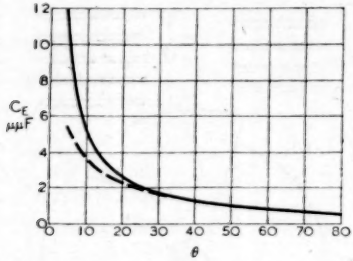


Fig. 7. *The edge capacitance of the trailing radial edges of the moving plates of a variable condenser. The full line curve is plotted from formula* (11) *and the broken line curve is based upon actual experiment.*

to the plate-shape in consequence of this approximate method of law error calculation will result in a moving plate radius which is correct above, say, $\theta = 15$ degrees and which is too great for angles below this. Therefore, if desired, a further correction for angles below 15 degrees may then be made by an estimation, trial and error method—a method which is rendered possible only by the excessive initial correction.

The drawing of Fig. 6 shows the trailing radial edges of the moving plates leaving the edges of the fixed plates. The angle θ is the angle by which the leading edges of the moving plates have entered the fixed plates. Referring to the drawing,

$$G = R\cos\tfrac{1}{2}\theta$$
$$D = 2R\sin\tfrac{1}{2}\theta$$
$$\delta G = \cos\tfrac{1}{2}\theta\delta R$$

If C_E is the edge capacitance

$$\delta C_E = \frac{M\cos\frac{1}{2}\theta\delta R}{4\pi(2R\sin\frac{1}{2}\theta)}$$

$$\frac{dC_E}{dR} = \frac{M\cos\frac{1}{2}\theta}{8\pi\sin\frac{1}{2}\theta}\cdot\frac{1}{R} \quad .. \quad .. \quad (9)$$

$$C_E = \frac{M\cos\frac{1}{2}\theta}{8\pi\sin\frac{1}{2}\theta}\int_r^{R_m}\frac{1}{R}\cdot dR$$

$$= \left[\frac{M\cos\frac{1}{2}\theta}{8\pi\sin\frac{1}{2}\theta}\log_e R + \text{constant}\right]_r^{R_m}$$

$$.. \quad .. \quad (10)$$

Therefore the edge capacitance between moving and fixed plate edges

$$= \frac{M}{8\pi}(\log_e R_m - \log_e r)\cot\tfrac{1}{2}\theta \quad \text{in cm units}$$

$$= \frac{M}{7.2\pi}(\log_e R_m - \log_e r)\cot\tfrac{1}{2}\theta \quad \mu\mu\text{F} \quad (11)$$

$$\frac{dC_E}{d\theta} = -\frac{M}{14.4\pi}(\log_e R_m - \log_e r)\operatorname{cosec}^2\tfrac{1}{2}\theta$$

$$.. \quad .. \quad (12)$$

$$= -\frac{\frac{M}{14.4\pi}(\log_e R_m - \log_e r)}{\sin^2\frac{1}{2}\theta}$$

$$\log_e\frac{dC_E}{d\theta} = -\log_e\frac{M}{14.4\pi}(\log_e R_m - \log_e r) - 2\log_e\sin\tfrac{1}{2}\theta$$

$$\frac{1}{\frac{dC_E}{d\theta}}\cdot\frac{d^2C_E}{d\theta^2} = -\frac{\cos\frac{1}{2}\theta}{\sin\frac{1}{2}\theta}$$

$$\frac{d^2C_E}{d\theta^2} = +\frac{M}{14.4\pi}(\log_e R_m - \log_e r)\cot\tfrac{1}{2}\theta\cdot\operatorname{cosec}^2\tfrac{1}{2}\theta$$

$$.. \quad .. \quad (13)$$

The full line curve of Fig. 7 shows the edge capacitance C_E calculated from formula (11) for the condenser of the example taken previously and where $M = 6.5$ cm. The broken line curve of the same figure shows the actual edge capacitance based upon the results of actual experiment. The difference between the two curves is seen to be quite small at all values of θ down to $\theta = 15$

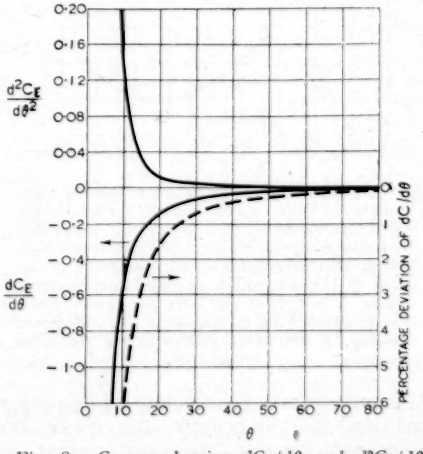


Fig. 8. *Curves showing $dC_E/d\theta$ and $d^2C_E/d\theta^2$ corresponding to the edge capacitance of Fig. 7. In addition, the broken line curve shows the deviation from linearity of $dC/d\theta$ of the whole condenser caused by $dC_E/d\theta$. The values of $dC_E/d\theta$ and $d^2C_E/d\theta^2$ used in plotting these curves have been calculated using formulae* (12) *and* (13) *respectively.*

degrees and the calculated values are quite useful at even smaller angles as will be seen later when the correction of plate-shape is dealt with.

The curves of Fig. 8 show, for the same example, the values of $dC_E/d\theta$ and $d^2C_E/d\theta^2$ using the formulae (12) and (13). Also shown in Fig. 8 is the percentage deviation of $dC/d\theta$, from its normal constant value of 8.35,

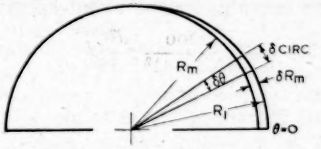


Fig. 9. *Showing in general terms the dimensioning of the plate-shape correction to compensate the edge capacitance of Figs. 7 and 8.*

due to $dC_E/d\theta$. As in the case of the edge capacitance, these curves are sensibly accurate only for angles over 15 degrees and are excessive for smaller angles because of the large ratio of dielectric gap to plate thickness of the example taken.

Since the " radial trailing edge " law error is due to design, a correction may be applied to compensate it. It is obvious that the radius of the moving plates must be increased where they commence to enter the fixed plates at $\theta = 0$. Let the corrected radius be termed $R_1 = R_m + \Delta R_m$ then, referring to the diagram of Fig. 9, it is seen that

$$\delta \text{ circ} = \frac{2\pi R_m}{360} . \delta\theta$$

$$\delta A = \delta \text{ circ.} \times \delta R_m$$

Therefore

$$\delta A = \frac{2\pi R_m}{360} . \delta\theta . \delta R_m$$

$$\delta C = k . \delta A$$

Therefore

$$\delta C = \frac{2\pi R_m}{360} . k . \delta\theta . \delta R_m$$

$$\delta R_m = \frac{\delta C}{\delta\theta} \cdot \frac{360}{2\pi R_m k}$$

and

$$\Delta R_m = \frac{180}{\pi k R_m} \cdot \left(-\frac{dC_E}{d\theta}\right) \quad .. \quad .. \quad (14)$$

(the negative algebraic sign is introduced because $dC_E/d\theta$ must be compensated)

Using formula (15) the corrected plate-shape has been computed for the example used previously and the results plotted in full line in Fig. 10. The broken line curve of the same figure shows the actual correction needed to produce perfect linearity of law—a correction based upon accurate experiment. Owing to the nature of the incorrect hypothesis employed in developing the approximate formulae (11), (12), (13) and (15) the calculated correction ΔR_m approaches infinity in the vicinity of $\theta = 0$ and is appreciably excessive at angles up to 10 degrees as a comparison of the two curves will show. Above 15 degrees the calculated curve may be regarded as sufficiently accurate for good law correction, for then the lengthening electrostatic field renders the air spaces between adjacent condenser plates negligible. For angles less than 15 degrees the excessive calculated correction provides that extra plate radius which is necessary to permit any further and more exact correction considered desirable at these small angles. Such further correction is effected by an estimation, trial and error method, and may be carried out from $\theta = 15$ down to, say, $\theta = 5$.

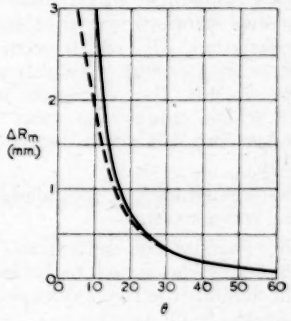


Fig. 10. *Showing, in full line, the plate-shape correction calculated from formula (15) together with the correction, in broken line, actually necessary to produce a perfectly linear law. These curves and those of Figs. 7 and 8 refer to the same example.*

In the region $\theta = 0$ to $\theta = 5$, the edge capacitance, not only of the *trailing* radial edges of the moving plates *leaving* the fixed plate edges, but also of the *leading* radial

$$\Delta R_m = + \frac{180}{\pi k R_m} . \frac{M}{14.4\pi} (\log_e R_m - \log_e r) \operatorname{cosec}^2 \tfrac{1}{2}\theta = + 0.022 \frac{M}{k R_m} (\log_e R_m - \log_e r) \operatorname{cosec}^2 \tfrac{1}{2}\theta \quad .. \quad .. \quad (15)$$

edges *entering* the fixed plates, is changing rapidly. Because of this, the standardised capacitance of a variable air condenser of the best quality is rarely used for interpolated values below $\theta = 10$ degrees or above $\theta = 170$ degrees, and so it is unnecessary to continue the correction below $\theta = 5$ degrees. In practice, therefore, the calculated correction is used in the design of the plate-shape above $\theta = 5$, and from $\theta = 5$ to $\theta = 0$ the radius R_1 is made constant so as not to increase the radial dimensions of the plate systems unnecessarily. This is shown in the drawing of Fig. 15 which appears later in the article.

The foregoing law imperfections of variable condensers are due merely to the geometry of the plate systems and to edge capacitance and therefore are independent of frequency. When a variable condenser is used at frequencies above, say, 1 Mc/s, however, the linearity of law is affected also by residual self-inductance; this effect being very dependent upon frequency.

The value of the self-inductance L_r of a variable air condenser of large dimensions and good design may be as much as 0.05 μH. The greater part of this is constant with θ but there is a component which varies with θ and is directly proportional to this angle. The total variation, ΔL_r, which occurs from $\theta = 0$ to $\theta = 160$ (*see* Fig. 11) rarely exceeds 0.1 L_r. It is not the variation of self-inductance which causes the most serious change of law but the fixed component of this residual.

If C_0 = the capacitance of the condenser at low frequencies

L_r = the residual self-inductance of the condenser (assumed to be constant throughout the range of capacitance, i.e. $\Delta L_r = 0$)

C_f = the effective capacitance of the condenser at any given high frequency.

$$C_0 = a\theta + b \qquad \text{where} \quad b = C_{\text{min.}}$$

$$\text{and} \quad a = \frac{C_{\text{max.}} - C_{\text{min.}}}{160}$$

$$\frac{dC_0}{d\theta} = a$$

$$C_f = \frac{C_0}{1 - \omega^2 L_r C_0}$$

$$\doteq C_0(1 + \omega^2 L_r C_0) \quad .. \quad .. \quad (16)$$

when $\omega^2 L_r C_0$ is reasonably small

$$C_f = (a\theta + b)\{1 + \omega^2 L_r(a\theta + b)\} \quad (17)$$

$$\frac{dC_f}{d\theta} = + a\{1 + 2\omega^2 L_r(a\theta + b)\} \quad (18)$$

From which the percentage increase of $dC_f/d\theta$ from $\theta = 0$ to $\theta = 160$

$$= 100\{2\omega^2 L_r(160a + b - b)\}$$

$$= + 3200\, a\omega^2 L_r \quad .. \quad .. \quad (19)$$

$$\frac{d^2C_f}{d\theta^2} = + 2a^2\omega^2 L_r \quad .. \quad .. \quad (20)$$

and the maximum error of interpolation

$$= + \frac{3200}{(N-1)^2} \cdot \frac{d^2C_f}{d\theta^2}$$

$$= 6400\, \frac{a^2\omega^2 L_r}{(N-1)^2} \quad .. \quad .. \quad (21)$$

In order to show the magnitude of this kind of law imperfection the case of a typical

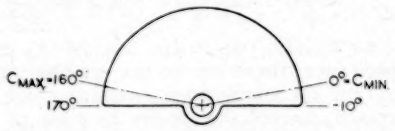


Fig. 11.

variable air condenser has been investigated by way of example. The condenser has a capacitance somewhat smaller than that of the example taken hitherto, the electrical dimensions being

$C_{\text{min.}} = 150\ \mu\mu\text{F}$ (at $\theta = 0$)
$C_{\text{max.}} = 950\ \mu\mu\text{F}$ (at $\theta = 160$)
$L_r = 0.05\ \mu\text{H}$
$\Delta L_r = 0$

Values of C_f, $dC_f/d\theta$, $d^2C_f/d\theta^2$ and interpolation error when $N = 8$, have been calculated from (17), (18), (20) and (21) and the results used to plot *logarithmically* the curves of Fig. 12. It will be seen that the non-linearity of law becomes noticeable at 1 Mc/s, appreciable at 3 Mc/s and serious at 5 Mc/s.

The value of $d^2C_f/d\theta^2$ is constant with θ as is the error *of capacitance* due to interpolation. The curves of $d^2C_f/d\theta^2$ and interpolation error therefore hold throughout the range of the condenser. The actual frequency error due to L_r, however, varies throughout the range of the condenser as is shown by the space between the two upper full line curves. The upper curve of the pair shows the frequency error at $C_{\text{max.}}$ and the lower that at $C_{\text{min.}}$ If the residual self-inductance is known exactly and is constant, these frequency errors may be eliminated entirely by applying a frequency correction to a capacitance calibration effected at low fre-

quency. In that case even the interpolation error caused by an appreciable value of $d^2C_f/d\theta^2$ may possibly be avoided by interpolating on a low frequency scale and *afterwards* applying the frequency correction. But if the exact value of L_r is unknown and perhaps varying with θ the condenser must be calibrated at the frequency at which it is to be used and the interpolation effected on the resulting high frequency scale bearing an appreciable value of $d^2C_f/d\theta^2$. Even so, the interpolation error shown in Fig. 12 may not be as serious as it appears because, at any given frequency, the frequency correction is at least ten times the interpolation error and the correction cannot generally be applied (or a radio frequency calibration imparted) with the accuracy associated with low frequency measurements. The interpolation error caused by $d^2C_f/d\theta^2$ therefore may be less than that of the actual calibrated capacitances.

The residual self-inductance of a variable condenser is rarely absolutely constant with θ, but comprises two components, L_r of constant value and ΔL_r which is variable with θ and, in most semi-circular plate condensers, is more or less proportional to θ. In order to ascertain the effect of ΔL_r upon the law, $dC_f/d\theta$ and $d^2C_f/d\theta^2$ must be first found as follows:

Let ΔL_r be the total increase of L_r from $\theta = 0$ to $\theta = 160$. Then at any angle θ the resultant residual self-inductance of the condenser

$$= L_r + \frac{1}{160}\Delta L_r\theta$$

Therefore, from (17),

$$C_f \doteqdot (a\theta + b)\{1 + \omega^2(L_r + \frac{1}{160}\Delta L_r\theta)(a\theta + b)\} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (22)$$

$$= a\theta + b + a^2\omega^2L_r\theta^2 + 2ab\omega^2L_r\theta + b^2\omega^2L_r + \frac{1}{160}a^2\omega^2\Delta L_r\theta^3 + \frac{2}{160}ab\omega^2\Delta L_r\theta^2 + \frac{1}{160}b^2\omega^2\Delta L_r\theta$$

$$= a\theta + b + \omega^2L_r(a^2\theta^2 + 2ab\theta + b^2) + \frac{1}{160}\omega^2\Delta L_r(a^2\theta^3 + 2ab\theta^2 + b^2\theta)$$

$$\frac{dC_f}{d\theta} = a + \omega^2L_r(2a^2\theta + 2ab) + \frac{1}{160}\omega^2\Delta L_r(3a^2\theta^2 + 4ab\theta + b^2)$$

$$= a + 2a\omega^2L_r(a\theta + b) + \frac{1}{160}\omega^2\Delta L_r(3a\theta + b)(a\theta + b) \quad .. \quad .. \quad .. \quad (23)$$

This expression has not been reduced to its simplest form but has been left with three distinct terms, the first applicable to a condenser with no residual self-inductance, the second representing the additional effect of a constant residual self-inductance and the third the still further effect of any linear variation of that residual.

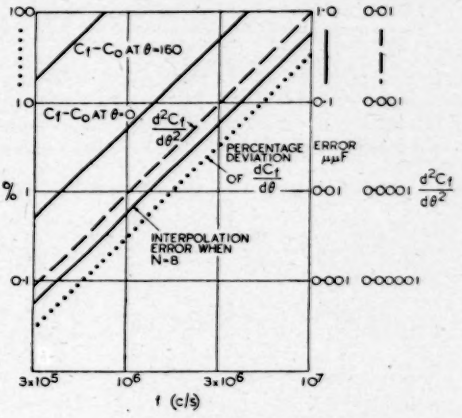


Fig. 12. *The effect of residual self-inductance upon the linearity of law of a variable condenser at various frequencies. The actual frequency correction $C_f - C_0$ due to this residual inductance is also shown.*

Differentiating the final term the effect of ΔL_r upon $d^2C_f/d\theta^2$ is found to be

$$\frac{1}{160}\omega^2\Delta L_r\{6a^2\theta + 4ab\}$$

$$= \frac{2}{160}a\omega^2\Delta L_r(3a\theta + 2b) \quad .. \quad .. \quad (24)$$

and adding this to $d^2C_f/d\theta^2$ already found for the constant inductance case the complete expression becomes:—

$$\frac{d^2C_f}{d\theta^2} = +2a^2\omega^2L_r + \frac{2}{160}a\omega^2\Delta L_r(3a\theta + 2b)$$

$$= 2a\omega^2\{aL_r + \frac{1}{160}(3a\theta + 2b)\Delta L_r\} \quad (25)$$

From (18) and (23) it is seen that the ratio of the effects upon $dC/d\theta$ of ΔL_r and L_r is given by:—

$$\frac{1/160\ \omega^2\Delta L_r(3a\theta+b)(a\theta+b)}{2a\omega^2 L_r(a\theta+b)} = \frac{\Delta L_r(3a\theta+b)}{320\ aL_r}$$

$$= \frac{1}{320}\cdot\frac{\Delta L_r}{L_r}\cdot\frac{3a\theta+b}{a}$$

At $\theta = 160$ if $C_{min.}$ is reasonably small compared with $C_{max.}$ the ratio of the effects

$$= \frac{3}{2}\frac{\Delta L_r}{L_r} \qquad .. \quad .. \quad .. \quad (26)$$

Similarly, from (20) and (25), the ratio of the values of $d^2C_f/d\theta^2$ due to ΔL_r and L_r is given by

$$\frac{2/160\ a\omega^2\Delta L_r(3a\theta+2b)}{2a^2\omega^2 L_r}$$

$$= \frac{1}{160}\cdot\frac{\Delta L_r}{L_r}\cdot\frac{3a\theta+2b}{a}$$

which at $\theta = 160$ if $C_{min.}$ is reasonably small compared with $C_{max.}$

$$= \frac{1}{160}\cdot\frac{\Delta L_r}{L_r}\cdot 3\theta$$

$$= 3\frac{\Delta L_r}{L_r} \qquad .. \quad .. \quad .. \quad (27)$$

this ratio rarely exceeds 0.3.

Using the above formulae (23) and (25) values of $dC_f/d\theta$ and $d^2C_f/d\theta^2$ have been calculated for the typical condenser already described but with the value of ΔL_r raised from zero to 0.005 μH. The curves III of Fig. 13 result. Also shown in Fig. 13 are the corresponding curves of the same condenser but with $\Delta L_r = 0$ (curves II) and with both $\Delta L_r = 0$ and $L_r = 0$ (curves I). Upon comparing curves II and III it is seen that the ratio of the effects of ΔL_r and L_r upon $dC_f/d\theta$ is as given by (26). It will also be observed that the ratio of the values of $d^2C_f/d\theta^2$ due to ΔL_r and L_r is as given by (27). The curves of Fig. 13 have been plotted for a frequency of 5 Mc/s. At this frequency the imperfection of law due to residual self-inductance is seen to be quite serious, whereas at 1 Mc/s it would have been scarcely appreciable owing to the fact that the effect of residual self-inductance is proportional to the square of the frequency.

Sometimes a variable condenser is intended for use exclusively at a single given frequency. For instance, one or more such standards, calibrated at different frequencies, may be associated with a bridge network or resonant circuit for the measurement of capacitance. In such cases a correction may be applied to the shape of the moving plate to compensate for the effect of the residual self-inductance $\Delta L_r + L_r$ at a given frequency. Such correction will compensate only for the effect upon the linearity of the law of the condenser—it will not compensate for the effect of the self-inductance upon the actual value of capacitance at any given value of θ.

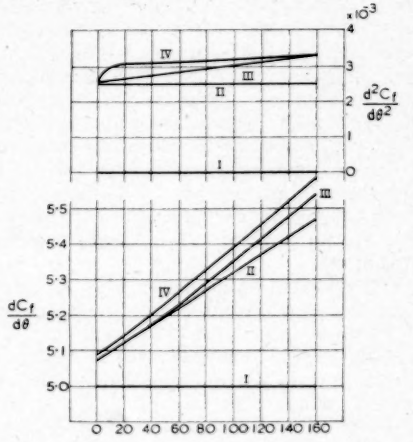


Fig. 13. *The effect of residual self-inductance $L_r + \Delta L_r$ on the linearity of law of a variable condenser at a frequency of 5 Mc/s.*

Case I	$L_r = 0$	$\Delta L_r = 0$
Case II	$L_r = 0.05\ \mu H$	$\Delta L_r = 0$
Case III	$L_r = 0.05\ \mu H$	$\Delta L_r = 0.005\ \mu H$
Case IV	$L_r = 0.05\ \mu H$	$\Delta L_r = 0.01\ \mu H$

In case III the variation of ΔL_r is linear throughout the range of the condenser whereas in case IV the variation is logarithmic.

In order to effect this compensation $dC_f/d\theta$ must be constant with θ and $d^2C_f/d\theta^2$ therefore zero. Therefore it is obvious that that part of $dC_f/d\theta$ which is variable with θ must be eliminated, leaving only the constant. To do this the area of the moving plate is reduced by an amount corresponding to the difference between $dC_f/d\theta$ and $dC_0/d\theta$. If the radius of the moving plates is R_m, the inner radius of the fixed plates is r and the amount of correction to R_m is $\Delta R_m'$, then after the manner of (14) it is seen that:

$$\Delta R_m' = \frac{180}{\pi k R_m}\left\{-\left(\frac{dC_f}{d\theta}-\frac{dC_0}{d\theta}\right)\right\} \qquad (28)$$

where the plate area to capacitance conversion factor

$$k = \frac{114.6\ (C_{max.} - C_{min.})}{160\ (R^2 - r^2)}$$

It follows from (23) that

$$\Delta R_m' = -\frac{180}{\pi}\cdot\frac{1}{kR_m}\left[2a\omega^2 L_r(a\theta+b) + \frac{1}{160}\omega^2\Delta L_r(a\theta+b)(3a\theta+b)\right]$$

$$= -\frac{180}{\pi}\cdot\frac{1}{kR_m}\cdot\omega^2(a\theta+b)\left\{2aL_r + \frac{1}{160}(3a+b)\Delta L_r\right\} \quad (29)$$

The negative algebraic sign indicates that the radius must be *reduced* by the amount $\Delta R_m'$. If the plate-shape is to be corrected for the effects of trailing edge capacitance also, it is obvious that the resultant complete correction must be the algebraic sum of the two individual corrections. Thus the final radius of the moving plate will be

$$R_2 = R_m + \Delta R_m + \Delta R_m'$$

As an example of a moving plate designed to have a linear law of capacitance at high frequency let us consider a typical variable condenser having the following electrical and geometrical dimensions:

$C_{\text{min.}}$ (at $\theta = 0$ deg.) 150 $\mu\mu$F
$C_{\text{max.}}$ (at $\theta = 160$ deg.) 950 $\mu\mu$F
$R_m = 10$ cm.
$r = 2$ cm.

Using the formula (29) the high frequency plate-shape correction $\Delta R_m'$ was calculated for a frequency of 5 Mc/s. The results are plotted in Fig. 14 together with correction ΔR_m calculated using formula (15). The resultant correction—the algebraic sum of ΔR_m and $\Delta R_m'$—is also shown. A drawing of the actual plate-shape resulting from this correction is given in Fig. 15. Although, as this drawing shows, the correction for residual self-inductance is appreciable at 5 Mc/s, it would be almost negligible if the frequency were lowered to 1 Mc/s, while it would be about four times (radially) that shown if the frequency were raised to 10 Mc/s. These relative corrections should help to give the reader some idea of the importance of the effect of self-inductance of the magnitude usually experienced.

Earlier in this article it was stated that ΔL_r rarely exceeded $0.1L_r$. The author's experience tends to show that in most cases in which the total variation of residual self-inductance exceeds this amount the variation is not roughly proportional to θ. In such cases most of the variation occurs in the region of minimum capacitance and may be expressed roughly by the law

$$0.77\Delta L_r(\log\theta - 1) \quad .. \quad .. \quad (30)$$

the total residual self-inductance at any angle θ being:

$$L_r + 0.77\Delta L_r(\log\theta - 1) \quad .. \quad (31)$$

and ΔL_r may be as much as 0.01 μH or even greater.

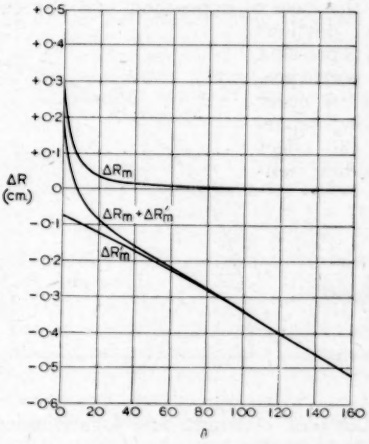


Fig. 14. *Showing the correction $\Delta R_m'$ necessary to maintain linearity of capacitance law at 5 Mc/s despite the effects of a residual self-inductance of* $(0.05 + 0.00008\theta)$ μH. *This correction is added to that, ΔR_m, necessary for trailing edge capacitance to give the resultant curve $\Delta R_m + \Delta R_m'$. The plate-shape corrected to this resultant curve is shown in the drawing of Fig.* 15.

When a law of this type prevails, the self-inductance changes rapidly with θ at minimum capacitance. Because of this it is felt necessary to investigate the effect of such a law upon the linearity of the capacitance law of a condenser at high frequency. More especially is this necessary owing to the larger total variation of self-inductance ΔL_r which usually accompanies this kind of law.

Expressions will therefore be formed for C_f, $dC_f/d\theta$ and $d^2C_f/d\theta^2$ and the effect will be observed upon the high frequency plate-shape correction already calculated. From (17) and (31)

$$C_f = (a\theta+b)\left[1 + \omega^2\{L_r + 0.77\Delta L_r (\log\theta - 1)\}(a\theta+b)\right] \quad .. \quad (32)$$

This may be expressed as the sum of three factors, the first of which represents the pure geometrical capacitance, the second the

effect of L_r and the third the additional effect of ΔL_r, thus

$$C_f = (a\theta + b) + \omega^2 L_r(a\theta + b)^2 + 0.77\omega^2 \Delta L_r \{(\log \theta - 1)(a\theta + b)^2\}$$

$$\frac{dC_f}{d\theta} = + a + 2a\omega^2 L_r(a\theta + b) + 0.77\omega^2 \Delta L_r[2a\{a\theta(\log \theta - 0.783) + b(\log \theta - 0.566)\} + 0.4343\, b^2\theta^{-1}] \quad .. \quad .. \quad (33)$$

As in the case of expression (23) the three distinct portions of this expression have been preserved in order to show, separately, the effect of residual self-inductance of constant and logarithmically variable character.

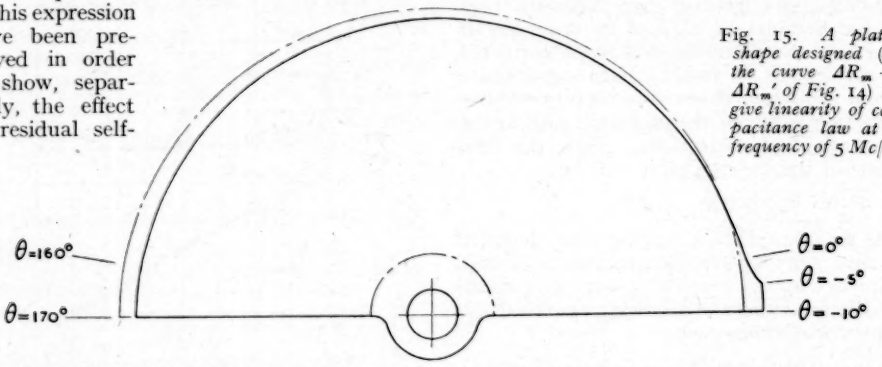


Fig. 15. *A plate-shape designed (to the curve $\Delta R_m + \Delta R_m'$ of Fig. 14) to give linearity of capacitance law at a frequency of 5 Mc/s.*

Differentiating the third portion of (33) we get

$$\frac{d^2C_f}{d\theta^2} = 0.77\omega^2 \Delta L_r[2a^2(\log \theta - 0.35) + 0.4343 b\theta^{-1}(2a - b\theta^{-1})] \quad .. \quad .. \quad (34)$$

Therefore, adding (34) to (20) the complete expression for $d^2C_f/d\theta^2$ is

$$\frac{d^2C_f}{d\theta^2} = 2a^2\omega^2 L_r + 0.77\,\omega^2 \Delta L_r[2a^2(\log \theta - 0.35) + 0.43 b\theta^{-1}(2a - b\theta^{-1})] \quad .. \quad .. \quad (35)$$

Curves IV of $dC_f/d\theta$ and $d^2C_f/d\theta^2$ to formulae (33) and (35) respectively have been added to Fig. 13 to show the effect of a large total ΔL_r (0.01μH) varying logarithmically, in comparison with that of a smaller ΔL_r (0.005μH) varying linearly. It is seen that the maximum effect upon $d^2C_f/d\theta^2$ in case IV is no greater than in case III but is practically uniform throughout the range of the condenser. The more rapid change of self-inductance in the former case at the low capacitance settings is off-set by the smaller effect of a given value of self-inductance upon the smaller value of capacitance.

The plate-shape correction for this kind of residual self-inductance is, from (28), given by

$$\Delta R_m'' = -\frac{180}{\pi} \cdot \frac{1}{kR_m}\left[2a\omega^2 L_r(a\theta + b) + 0.77\omega^2 \Delta L_r[2a\{a\theta(\log\theta - 0.783) + b(\log\theta - 0.566)\} + 0.4343\, b^2\theta^{-1}]\right] \quad .. \quad .. \quad (36)$$

This correction results in a plate-shape very little different from that depicted in Figs. 14 and 15. The corrected radii are about 0.01 cm. less at $\theta = 0$ and 0.04 cm. less at $\theta = 160$. Such differences would not be noticeable in the reduced reproduction of the actual plate.

From this investigation of the logarithmic law of variation of residual self-inductance it is seen that the actual nature of the variation is not very important* either in the interpolation errors introduced or in the plate-shape correction. The constant component, L_r, usually affords the predominating influence and the *magnitude* of the total change, ΔL_r, is next in order of importance, the *law* of the change of ΔL_r having little effect.

In conclusion, the author would express the hope that the reader has gained a knowledge of the various factors which govern inaccuracy of interpolation. Engineers and research workers in the communication industry are demanding capacitance standards of ever increasing accuracy. For this reason it is necessary to investigate thoroughly all possible sources of law imperfection. Only after this has been done can the law of a variable condenser be said to be beyond suspicion.

* An exact knowledge of the nature of the variation of self-inductance is necessary, however, for the determination of the frequency correction to the actual capacitance value of a variable condenser at any setting θ.

PRODUCING RECTANGULAR R.F. PULSES OF KNOWN AMPLITUDE*

By W. R. Piggott, B.Sc

(Radio Division, National Physical Laboratory).

ABSTRACT. — The paper describes the design of an equipment which generates rectangular pulses of radio-frequency energy, the amplitude, duration and recurrence frequency of the pulses being independently variable. The accuracy and stability of the equipment is equal to that of a conventional standard-signal generator. A brief description of the application of the instrument to the study of the transient and phase response of networks is also given in an Appendix.

1. Experimental Requirements

THE apparatus for the production of standard rectangular radio-frequency pulses can be divided into sections, certain of which can be changed in form without altering the mode of operation of the complete apparatus. These are :—

(i) A source of radio-frequency potential ;
(ii) A standard attenuator ;
(iii) A radio-frequency voltmeter or milliammeter ;
(iv) A low-capacitance electronic switch and
(v) A source of rectangular pulse modulation of variable pulse length, and recurrence frequency.

In practice, (i), (ii) and (iii) can be combined in the form of a commercial standard-signal generator and (iv) and (v) be added as an external pulse modulator unit. In cases where a complete new equipment is required it is best designed as one unit. A number of different units have been produced for specific purposes at the National Physical Laboratory and certain of these of general interest are discussed below.

An extremely simple example of an external modulator unit for use with a signal generator having a symmetrical output will be described first.

2. Symmetrical Modulator Unit

A typical unit was designed to work in conjunction with a Marconi-Ekco type TF 390 F/3 signal generator covering the ranges 1.6 to 2.4 Mc/s and 18 to 100 Mc/s. The radio-frequency continuous-wave output is thus known and the design problem is to modulate this output so that during a time period T it is equal to a known fraction of the nominal output and for other times it is zero. It is necessary that the ratio of output (pulse) to nominal output should remain constant for all probable changes in applied potentials in the circuits, input amplitudes, and output loads. This suggests the use of a neutralised push-pull cathode-follower circuit as this circuit has a very low output impedance and the stage gain is approximately unity provided that the R.F. input impedance of the load is not too small relative to the output impedance of the circuit. It is also independent of changes in the operating conditions of the valves. A satisfactory circuit is shown in Fig. 1. The radio-frequency input is applied to the grids of the valves through the blocking condensers C_1 and the pulse modulation is also applied to these grids *via* the H.F. chokes L_1 and L_3. Normally the valves are biased beyond cut-off by R_5 so that they are inert and the output is due to leakage through stray capacitances and the grid-cathode capacitances of the valves. This is made zero by adjusting the neutralising condensers C_n which have the effect of feeding out-of-phase potentials into the cathode loads.

At high frequencies the effective input impedance consists of the grid-cathode impedance, which is high for a Mullard EF50 valve under these conditions, in parallel with that due to half the grid-anode circuit capacitance (about 5 $\mu\mu$F). It is practically purely capacitive and is only important in that it fixes a lower limit for the values of the coupling capacitances C_1. On low frequencies the input impedance is controlled by the grid chokes. If we consider a valve having a mutual conductance g and a cathode load impedance Z, the anode

* MS. accepted by the Editor, October, 1944.

being connected to earth by a low impedance, the output signal potential is given by :

$$V_0 = \frac{V_i}{1 + gZ} \cdot gZ$$

or $$V_0 = V_i\left(1 + \frac{1}{gZ}\right)^{-1} \quad .. \quad .. \quad (1)$$

where V_i is the input signal potential.

If $gZ > 1$ $$V_0 = V_i\left(1 - \frac{1}{gZ}\right) \quad .. \quad (2)$$

If $gZ \gg 1$ this reduces to

$$V_0 = V_i$$

and the effective output impedance of the circuit is $\frac{1}{g}$ .. .. (3)

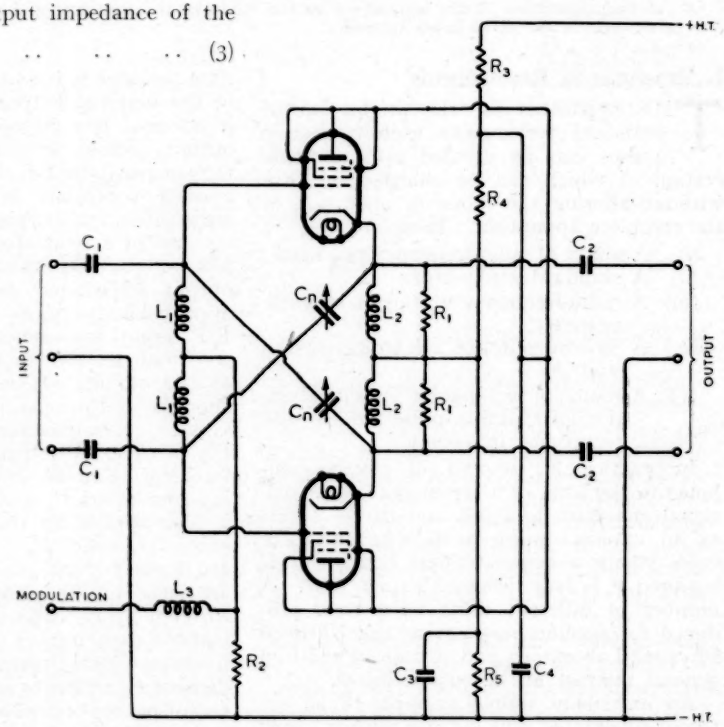


Fig. 1. C_1, 50$\mu\mu$F; C_2, 100μF (greater if very low output impedance or low frequency is needed); C_3, 50μF, 50-volt D.C. and 0.01μF (mica) in parallel; C_4, 8μF, 500-volt D.C. and 0.01μF (mica) in parallel; C_n, 2 — 10$\mu\mu$F, variable; R_1, 3,000Ω (less if very low output impedance is needed); R_2, 100,000Ω (less if very short pulses are required); R_3, 50,000Ω, 2 watt; R_4, 10,000Ω, 2 watt; R_5, 5,000Ω, 2 watt; Valves are Mullard EF50; H.T. 400 volts max.; all chokes are Eddystone 1.25mH. The component values, with the exception of C_n are not critical.

Thus, if it is possible to make $gZ \gg 1$ the output and input will be equal and will be independent of small changes in valve characteristics or operating conditions. If $gZ > 1$ the output is less than the input but the negative feed-back will still render the output practically independent of changes in applied potentials.

In this particular application it is desirable to make Z as small as possible. Hence it is necessary to use very high slope valves. In practice the Mullard EF50 proves very satisfactory as it has a mutual conductance of 6.5 mA/V and a reasonably high input impedance. The output impedance of the stage is thus theoretically of the order 200 to 300 ohms cathode to cathode. In practice, the actual impedance proves to be less than this. The cathode loads consist of R.F. chokes L_2 shunted by resistances R_1. The chokes prevent the transfer of the low-frequency modulation to the output circuits which would occur if resistive loads were used and thus prevents the modulation from changing the valve bias. The value of the resistances depends on the minimum load into which the circuit is to feed and their sole uses are to define gZ and to prevent shock excitation of the chokes. A rectangular positive pulse is now applied to the grids of the valves and alters the grid bias to the normal value. The R.F. input signal is then amplified according to equation (1) and this gives an output signal proportional to the input.

The maximum undistorted amplitude available is proportional to the anode

potential and to Z. For large values of Z it approaches half the applied anode potential and for Z about 1,000 ohms it is more than 20 volts when the anode potential is 350 volts. An exact figure for the ratio of pulse signal to leakage signal cannot be given as the leakage signal actually encountered was radiated directly from the signal generator equipment.* Extremely large ratios could be obtained without trouble and the setting of the neutralising condensers was constant over the range in frequency given by the signal generator.

It is necessary for the input circuit of the electronic switch to be able to pass the rectangular pulse without distortion. Therefore the series impedance $L_1 + L_3$ must be small at modulation frequencies and also the total capacitance which has to be charged or discharged by the pulse must be as small as possible. Now, as the signal generator is equivalent to a short circuit across the input to the unit, this capacitance is made up of the two blocking condensers C_1 and the grid capacitances in parallel. The size of the condensers C_1 is also controlled by the minimum radio frequency desired. This is of particular importance when very narrow pulses are required as there is clearly a lower limit to the radio frequency which can be modulated by a given pulse without either distortion or loss in amplitude. In the example described this limit was set at 1.6 Mc/s, the lowest frequency of the signal generator, and the system was designed on that basis. With this limitation, pulses of from 5 to 10 microseconds and longer could be easily obtained. This was a convenient minimum for the pulse generator used and the problem was, therefore, not investigated further though there is little doubt that still narrower pulses can be obtained on these low frequencies by careful design.

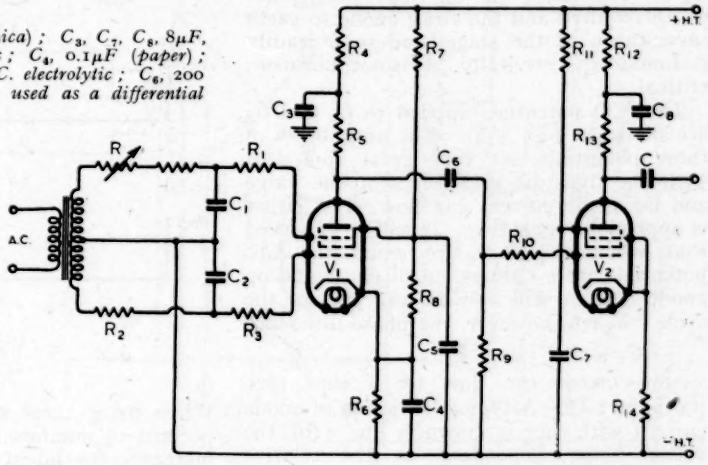


Fig. 2. C_1, C_2, 0.01μF (*mica*); C_3, C_7, C_8, 8μF, 500-*volt D.C. electrolytic*; C_4, 0.1μF (*paper*); C_5, 0.4μF, 300-*volt D.C. electrolytic*; C_6, 200 $\mu\mu F$. (Note. C_6 *can be used as a differential condenser to give still narrower pulses at the coil of less output amplitude. In this case* C_5 *should be short-circuited with a* 0.01μF *mica condenser*). R, 0.1$M\Omega$ *and* 0.1 $M\Omega$ *variable or any other pair of resistances giving approximately the same total. The variable resistance controls the range in pulse widths available.* R_1, R_3, 50,000Ω, $\frac{1}{4}$ *watt*; R_2, 250,000Ω 1 *watt*; R_4, R_9, R_{12}, 25,000Ω, $\frac{1}{4}$ *watt*; R_5, R_7, R_{11}, R_{13}, 150,000Ω, 1 *watt*; R_6, R_{14}, 2,000Ω, 1 *watt* (R_{14} *may be decreased to zero*); R_9, 1$M\Omega$, $\frac{1}{4}$ *watt*; R_{10}, 3,000Ω, $\frac{1}{4}$ *watt (less if narrow pulses required). The transformer should be rated at* 500–0–500 *volts*, 10 *mA output. An AF6C or a pair of AF3 transformers are also satisfactory. Lower outputs can be used with a proportional increase in the length of the smallest rectangular pulse.*

3. Simple A.C. Mains Controlled Pulse Generator

The transformer is driven from the A.C. mains and the phase position of the pulse may be altered, if desired, by means of a conventional bridge type phase-shifting circuit.

The two halves of the secondary of the transformer are connected through phase-shifting networks RC_1, R_2C_2 to the control grid (G_1) and suppressor grid (G_3) of a pentode valve V_1.

The circuit is completed through a bias

* Investigation showed that this radiation was due to a fault in the instrument which was corrected by the manufacturers. The stray leakage was then negligible.

resistor R_6 forming part of the potential divider R_6, R_7, R_8, which controls the D.C. potentials between the grids and cathode of the valve. The screen grid potential is small and the bias is adjusted so that, when the phase shifts introduced by RC_1, R_2C_2 are equal, the anode current of the valve is zero.

The anode load resistance R_5 is made as large as possible in order to obtain a short dynamic grid base. The optimum value of R_5 is dependent on the narrowest pulse width required and the stray anode to earth capacitance of the stage, and may readily be found experimentally. It is not, however, critical.

The A.C. potentials applied to G_1 and G_3 are shown in Fig. 3 (a). The amplitudes of these potentials are very great compared with the dynamic grid bases of the valve and no anode current can flow when either is appreciably negative. It will be observed that, when RC_1, R_2C_2 are equal, the A.C. potentials are π radians out of phase and no anode current will flow at any part of the cycle. When, however, the phase difference

$$RC_1 - R_2C_2 = \pm\theta$$

anode current can flow for a time proportional to θ. A typical variation of anode current with time is shown in Fig. 3 (b), the actual shape depending on the relative magnitudes of the applied potential and the grid bias of the valve.

The potential changes at the anode of V_1 are applied to the grid of V_2 and amplified and rendered more rectangular by that valve, thus giving the final modulation potentials shown in Fig. 3 (c).

The phase angle θ can be changed by varying the resistances R connecting the transformer to the suppressor grid of the pentode. The range of pulse lengths provided can be varied between wide limits by varying the capacitance C_1 and resistance R. In practice, a convenient ratio of maximum to minimum pulse length is about 10 : 1 as this enables a given width to be repeated with great accuracy and ease. For larger ratios a high quality rheostat and condenser are essential to enable exact repetition to be maintained, and it is preferable to provide a switch giving several preset values of C_1.

By using an A.F. type transformer this circuit can be driven by a valve oscillator and any pulse recurrence-frequency obtained up to the maximum frequency passed by the transformer. The narrowest pulse width available for a given input A.F. voltage is inversely proportional to the frequency. Thus a circuit which will give 10 microsecond pulses using 50 c/s can give 0.1 microsecond pulses using 5,000 c/s.

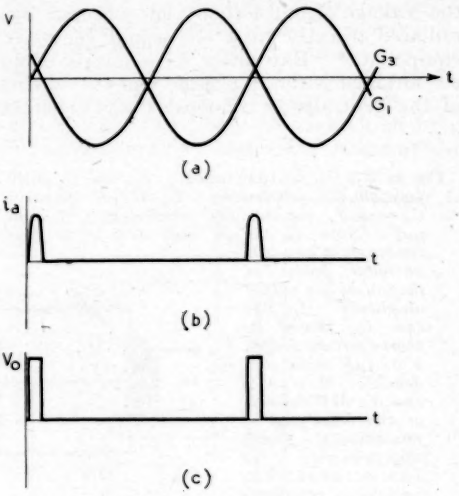


Fig. 3.

When using these narrow pulses it is important to minimise stray capacitances and maintain the fidelity of the circuit of the amplifier. Conventional wide band technique should be used and the amplifier should be capable of handling frequencies up to the inverse of the pulse width. The pulses can also be locked to an arbitrary signal recurrence frequency by locking the oscillator to that frequency.

4. Constructional

The above equipment may be assembled in one metal box complete with its power supply, in which case the only experimental precautions necessary are as follows :—

(a) The input and output leads and impedance elements of the electronic switch must be kept small, symmetrical and screened from each other.

(b) The whole electronic switch should be electrically screened from the modulator.

(c) The leads and terminating impedances of the signal generator must be completely screened and earthed to the electronic switch unit.

(d) It is essential that the anode decoupling condenser in the electronic switch

be effective at all the radio frequencies required as otherwise the operation will become unstable.

If the neutralising condensers are arranged so that they may be adjusted while the unit is in use, stray R.F. pick-up from the signal generator can be minimised with their aid. These condensers must be well screened and be operated by non-conducting spindles.

Alternatively, the modulator and power supply can be assembled as a unit and the electronic switch be mounted as a small screened probe unit. In this case it is essential that the screening be very good and that the modulator feed be made through a low-loss low-capacitance cable.* Otherwise serious distortion of the rectangular pulse occurs.

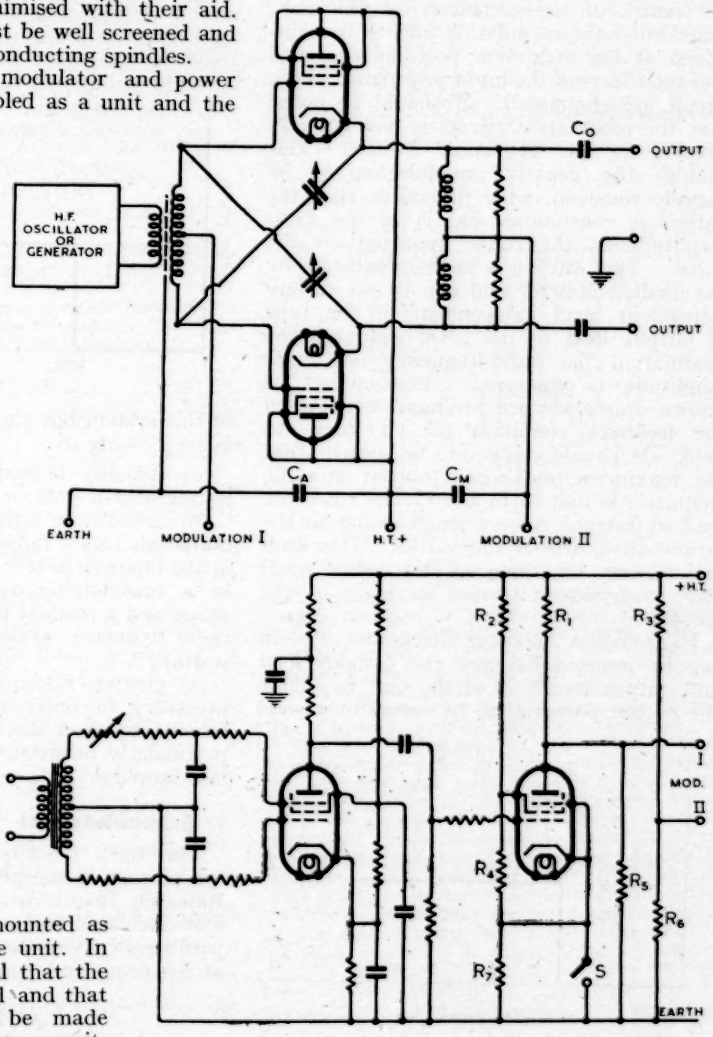


Fig. 4. *The component values are similar to those given in earlier figures except for the following alterations :— C_a, 8μF + 0.01μF (non-inductive); C_m, 8μF + 0.1μF (non-inductive); C_o, 0.01 μF (mica); R_1, 100,000Ω; R_2, 150,000Ω; R_3, 5,000Ω, 6 watts; R_4, 75,000Ω,; R_5, 50,000Ω; R_6, 2,500 Ω, 6 watts; R_7, 10,000Ω. S is a low capacitance switch for obtaining a C.W. output. C_o should have a low impedance relative to the load. R_2, R_5 and R_6 are adjusted so that the electronic switch has a normal bias of about −2 volts when S is open and can be biased beyond cut-off with S closed. The output is connected to a C.W. measuring instrument and circuit suitable for the application required.*

5. Complete Pulse Modulated Signal Generator

Considerable simplification and an increase in convenience and overall accuracy can be obtained if the signal generator and pulse equipment are combined. It is also possible to widen greatly the radio-frequency range for a given pulse shape and to decrease the output impedance to any required extent. The equipment in this form has particular applications in the case of the problem

* Since the writing of this paper pulse transformers have been developed which may be used satisfactorily to give a very convenient unit.

of pulse field-strength measurements and measurements of the transient behaviour of extended systems such as transmission lines and aerials. A suitable circuit is shown in Fig. 4.

By feeding the modulation potential into the centre of the secondary of the R.F. transformer the modulation fidelity is maintained at the maximum possible level and also the effects of the input impedance of the circuit are eliminated. It should be noted that the modulation circuit is now directly coupled to the electronic switch. This enables the negative modulation to be entirely removed, with the result that the output is continuous and is of the same amplitude as the radio frequency in the pulse. This output is then monitored by the diode voltmeter and can be set to any convenient level independent of the type of output load in use. On applying the modulation the radio-frequency maximum amplitude is unaltered. Thus pulses of known amplitude are produced even when the feedback condition $gZ > 1$ does not hold. It should, however, be noted that the maximum undistorted output of radio frequency is limited to a few volts when the load impedance is very small owing to the power dissipated in the valves. This limitation can be removed by using small H.F. transmitting triodes in place of the EF 50s.

If desired a balanced attenuator system can be inserted between the cathode load and output terminals of the unit to enable the output potential to be varied over wide

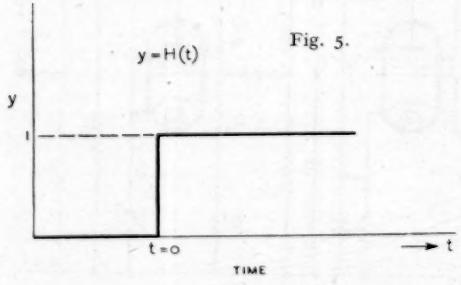


Fig. 5.

ranges of amplitude. In this case the minimum load into which the unit can feed without distortion is controlled by the attenuator system and it is essential to examine the transient response of the system when very narrow pulses are used.

6. General

Both of the units described above can be used without alteration to give an asymmetrical output provided that the load is large compared with the effective cathode impedance, otherwise it is best to use the second circuit and to replace the cathode impedance by a R.F. transformer monitored across its secondary winding. It is possible to build completely asymmetrical versions

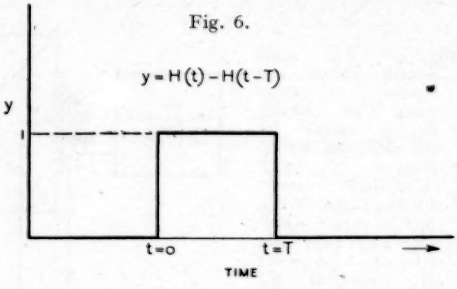


Fig. 6.

of this system but they are much less satisfactory owing to

(a) difficulty in maintaining the neutralisation over a wide frequency band ;

(b) difficulty in separating the modulation potentials and radio-frequency potentials in the input circuits. (This is liable to result in a considerable distortion of the pulse shape and a marked limitation of the lowest radio frequency available for a given pulse width) ;

(c) greater filtering and screening being necessary in order to prevent stray link circuits between the input and output and particularly between these and the modulation amplifier.

7. Acknowledgment

The work described above was carried out as part of the programme of the Radio Research Board, to whom this paper was first circulated in January, 1941. It is now published by permission of the Department of Scientific and Industrial Research.

APPENDIX

Application of a pulse signal generator to the adjustment of transient response characteristics

The utility of a standard pulse modulated signal generator for examining the behaviour of pulse equipment and for pulse field-strength measurement is immediately obvious, but it is not generally realised that this instrument is capable of demonstrating the response of a given system to

any type of transient or continuous signal in a quick and convenient manner. This property is of very great value in complex problems in which transient response is of importance, as the latter cannot be predicted from a knowledge of the response to continuous-wave inputs alone, e.g. it is possible to build filter circuits which will reject certain continuous-wave signals almost completely, but which will not operate in the case where the signal frequencies are modulated by transients. A standard transient is particularly convenient when it is necessary to adjust a complex system so as to produce given response characteristics as this is equivalent to adjusting the system until the transient is distorted to a given form.

The simplest transient which can be used theoretically is the Heaviside transient.

$$H(t) = \tfrac{1}{2} + \frac{1}{\pi}\int_0^\infty \frac{1}{\omega}\sin \omega t \,.\, d\omega \quad .. \quad .. \quad (4)$$

which is shown in Fig. 5, but for practical reasons it is better to use the transient made from the sum of the functions $H(t)$ and $-H(t-T)$.

This is shown in Fig. 6 which represents a rectangular pulse of width T seconds. This transient may be represented by the equation :—

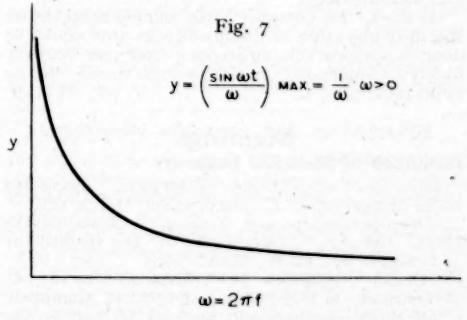
$$H(t) - H(t-T) = \frac{2}{\pi}\int_0^\infty \frac{\sin \frac{\omega T}{2}}{\omega} \cos \omega(t - \frac{T}{2}) \,.\, d\omega \quad .. \quad .. \quad (5)$$

which has maxima at $\omega = (2n-1)\frac{\pi}{T}$

and minima at $2n\frac{\pi}{T}$

It should be noticed that, if the pulse has a

Fig. 7



recurrence frequency at $\frac{1}{2s}$ per second, it can be represented by a Fourier series using the harmonics of $\frac{1}{2s}$ only. The form of the equation is the same as equation (5) with the integral replaced by a sum containing

$$\omega = \frac{n\pi}{s} \quad (n \text{ an integer}).$$

The frequency spectra $A(\omega) : \omega$ of the two transients are sketched in Figs. 7 and 8.

Mathematical methods of obtaining the result of applying these transients to a given system have been examined by many authors[1, 2, 3]. It is found that complex cases can usually be reduced to the superposition of a limited number of typical forms of distortion. A good understanding of the technique involved can be obtained by applying these transients to simple electrical circuits having known amplitude and phase characteristics. The

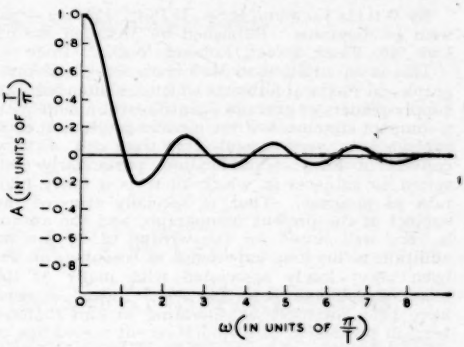


Fig. 8.

$$A = \frac{2T}{\pi}\left[\frac{\sin \omega \frac{T}{2}}{\omega T} \,.\, \cos \omega(t - \frac{T}{2})\right]$$

$$For \quad t = 0, \; A = \frac{T}{\pi}\left[\frac{\sin \omega T}{\omega T}\right]$$

$$For \quad t = \frac{T}{2}, \quad A = \frac{T}{\pi}\left[\frac{\sin \frac{\omega T}{2}}{\frac{\omega T}{2}}\right]$$

Giving the extreme values of A.

resulting data shows clearly the effect of phase and amplitude changes with frequency and these results can then be used to predict the changes needed in a system to provide given forms of response curves. Physically, the amplitude-frequency response completely defines the continuous state of a linear network, whereas to define the transient response it is also necessary to know the connection between phase and frequency.

The recurrent rectangular pulse can be made to define the response to all frequencies by varying T and s (equation 5) but usually gives adequate solutions in practice if s is constant and two values of T are considered. In the case of non-linear systems it is also necessary to know the input-output amplitude response and the effective time constants of the non-linear parts of the network. This problem does not lend itself to mathematical treatment and is best examined experimentally. A short account of the distortion of transients under simplified conditions is given in Starr's " Electric Circuits and Wave Filters."[4]

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[2 3] Bush, V. " Operational Circuit Analysis ", (1929), Wiley.

[2 3] Carson, J. R. " Electric Circuit Theory and Operationa Calculus ", (1926), McGraw-Hill.

[4] Starr, A. T. " Electric Circuits and Wave Filters ", (1938), Pitman.

* Bibliographies will be found in the books by Bush and Carson and in modern television journals.

BOOK REVIEW

High Frequency Transmission Lines

By WILLIS JACKSON, D.Sc., D.Phil. Pp. 152 + vii with 46 diagrams. Published by Methuen & Co., Ltd., 36, Essex Street, London, W.C.2. Price 6s.

This is an addition to Methuen's series of Monographs on Physical Subjects which are intended " to supply readers of average scientific attainment with a compact statement of the modern position in each subject "—a very useful objective and a very convenient form of publication, particularly well suited to subjects in which there is a fairly high rate of progress. That is specially true of the subject of the present monograph, and the author is very well suited for the writing of it, for, in addition to his long experience in teaching, he has been very closely associated with many of the recent developments in this field. Indeed, it must have been intensely exasperating to him to have been in possession of so much recent knowledge of the subject which could not, for various reasons, chiefly those of security, be included in the present edition. These gaps, however, he will, perhaps, be able to fill in happier times. Meanwhile the present volume gives a concise and lucid statement of as much recent information as he, or anyone else, could divulge in the existing circumstances.

He begins, very wisely, with a bird's-eye view of the field of application of transmission lines at very high frequencies, and so puts the subject into its proper perspective in relation to modern radio technique. This chapter, by the way, contains the only passage about which the present reviewer felt at all uneasy—a statement that the total power loss in a feeder carrying forward and reflected waves depends on their individual amplitudes. This is justifiable but might be misinterpreted, for, of course, the total loss in any element does not, in fact, depend on the individual amplitudes but on their algebraic sum. However, the detailed analysis given in a later chapter should prevent any permanent misconception.

The second chapter deals with basic equations, and is specially good in the way in which transmission lines are linked up with the whole vitally important subject of guided waves in general; the usual transmission line equations being derived from Maxwell's field equations applied to the type of wave (transverse, electromagnetic, or T.E.M.) associated with linear twin and coaxial conductors. The distinction between dielectric loss and conductor loss in relation to the field configuration is very clearly established by this mode of presentation.

The third chapter, on the propagation characteristics of lines, gives not only the usual theoretical derivations of these characteristics from the line equations, but also a great deal of useful and practical detailed information about the effect of the material constants and the geometry of transmission lines on their propagation characteristics and their performance—even including such eminently practical matters as the effects of small degrees of eccentricity, and the maximum power ratings of feeders.

Chapter four is about the behaviour of terminated lines. The present reviewer has a decided bias in favour of description in terms of reflection and transmission coefficients rather than circuit impedances—some might say that he has a bee in his bonnet here—and was therefore glad to find that the subject is considered mainly in those terms and related to the field equations. This treatment shows to special advantage in the consideration of the effect of a discontinuity in the medium and of short-circuited and " correctly terminated lines." The author, in conjunction with L. G. H. Huxley, has made a very useful contribution to the technique of true non-reflective termination.

The fifth chapter, on resonant lines, covers a wide range of useful practical applications, including some of comparatively recent development, in most of which the author writes on the basis of considerable personal experience. This is true, for example, of the measurement of dielectric properties at very high frequencies by means of a closed coaxial resonator. This chapter also includes a description of the Chipman method of measuring impedances in general and cable characteristics in particular. As developed by Dr. Essen, of the Radio Division of the National Physical Laboratory, this has become a well-established technique which has played an important part in the rapid growth of the high-frequency cable industry in this country.

The sixth and final chapter covers a subject to which the author, in association with L. G. H. Huxley, has recently made a substantial contribution, namely, circle diagrams of impedance—their derivation and application both to the interpretation in graphical form of the behaviour of transmission line systems, and to what would otherwise be lengthy and laborious computations in design and measurement.

In short, this compact little volume achieves its specified objective as completely as this could be done in present circumstances, and can be very highly commended to those interested in its important subject.

F. M. C.

Meetings

Institution of Electrical Engineers

Radio Section.—" Colour Television," discussion to be opened by L. C. Jesty, B.Sc., March 13th.

" Apprenticeship and Trainee Systems in the Radio Industry," discussion to be opened by J. Greig, M.Sc., Ph.D., March 20th.

" Studio Technique in Television," by D. C. Birkenshaw, M.B.E., M.A., and D. R. Campbell.

All these meetings will be held at 5.30 at the I.E.E., Savoy Place, London, W.C.2.

Cambridge Radio Group.—" Multipath Interference in Television Transmission," by D. I. Lawson, M.Sc., March 13th, at 6 o'clock at the Technical College, Collier Road, Cambridge.

" The Design and Manufacture of Radio Valves," by G. Liebmann, Ph.D., March 27th, at 7 o'clock at the University Engineering Department, Trumpington Street, Cambridge.

North-Western Radio Group.—" Recording and Reproduction of Sound," discussion to be opened by F. E. Williams, M.Sc., March 23rd, at 6 o'clock, at the Engineers' Club, Albert Square, Manchester.

British Institution of Radio Engineers

North-Eastern Section.—" Proposals for Television and Broadcasting Transmission Systems,"

by W. A. Beatty, March 14th, at 6 o'clock in the Neville Hall, Newcastle-on-Tyne.

Royal Society of Arts

"The Making of a Gramophone Record," by H. W. Bowen, March 21st, at 1.45 at the Royal Society of Arts, John Adam St., London, W.C.2.

Institute of Physics

South Wales Branch.—The inaugural meeting of the Branch will be held on March 10th at 2.30 in the Physics Department of University College, Swansea (Singleton Park). Particulars of the Branch may be obtained from Dr. T. V. I. Starkey, the Technical College, Mount Pleasant, Swansea.

Institution of Electronics

North-West Branch.—"Pulse Generation," by Dr. F. J. G. van den Bosch, March 23rd, at 6.30, at the Reynolds Hall, College of Technology, Manchester.

City and Guilds Radio Society

"The Transmission of Television Signals over Ordinary Non-loaded Telephone Pairs," by A. R. A. Rendall, Ph.D., on March 9th.

"Some Problems in Instrument Design," by F. E. J. Ockenden on March 16th.

Both meetings will commence at 5.15 at the City and Guilds College, Exhibition Road, S.W.7.

WIRELESS PATENTS

A Summary of Recently Accepted Specifications

ACOUSTICS AND AUDIO-FREQUENCY CIRCUITS AND APPARATUS

564 796.—A.V.C. system which also operates to discriminate against unwanted frequencies in a circuit comprising voice and other signalling currents.

E. T. Jones. Application date 9th April, 1943.

565 367.—Loudspeaker in which the speech coil is wound around the free edges of a conical diaphragm, which is flexibly clamped at its centre.

W. H. Allan. Application date 4th May, 1943.

AERIALS AND AERIAL SYSTEMS

565 287.—Method of balancing the feed lines to an aerial of the "hollow" tower or dipole type which is energised through an end "capacitance cap."

Standard Telephones and Cables Ltd. (assignees of M. A. Rote). Convention date (U.S.A.) 4th April, 1942.

RECEIVING CIRCUITS AND APPARATUS

564 710.—Balanced bridge circuit including a non-Ohmic device, such as a Thermistor, for stabilising the voltage supply to amplifying or measuring valves.

Standard Telephones and Cables Ltd. and M. M. Levy. Application date 5th April, 1943.

564 731.—Super-regenerative receiver in which the quenching frequency is generated by a velocity-modulating device incorporated in a back-coupled triode valve.

Marconi's W.T. Co. Ltd. and G. G. Banks. Application date 9th May, 1941.

564 744.—Combination of a heat-sensitive resistance, such as a Thermistor, and an inductive reactance for smoothing the ripple from a D.C. generator.

Standard Telephones and Cables Ltd. and C. T. Scully. Application date 5th February, 1943.

TELEVISION CIRCUITS AND APPARATUS

564 824.—Amplifier chain, comprising cathode followers, designed to feed a wide range, say, of television signals to a number of low-impedance loads in parallel.

E. L. C. White. Application date 9th April, 1943.

TRANSMITTING CIRCUITS AND APPARATUS

564 822.—Automatic cut-out circuits in which a temperature-sensitive device, such as a Thermistor, is utilised to protect a thermionic valve or other device against overload.

Standard Telephones and Cables Ltd. and P. K. Chatterjea. Application date 9th April, 1943.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

564 826.—Electrode arrangement and feed-back circuit for detecting and amplifying high frequencies in a tube of the velocity-modulation type.

Standard Telephones and Cables Ltd. (assignees of C. V. Litton). Convention date (U.S.A.) 13th July, 1940.

564 836.—Valve holder of the disc type constructed and coated to minimise inter-contact capacitance.

J. E. Cope and Pye Ltd. Application date 15th January, 1943.

564 858.—Electrode arrangement and operation of an oscillation generator of the velocity-modulation type, particularly for feeding H.F. energy to a wave guide.

Standard Telephones and Cables Ltd. (assignees of J. B. Fisk). Convention date (U.S.A.) 5th June, 1940.

564 890.—Arrangement for securing useful interaction between an electron stream and the electric fields in an energised wave guide which is folded about the stream in an evacuated tube.

Electrical Research Products Inc. Convention date (U.S.A.) 17th May, 1940.

565 485.—Construction of the glass stub, and method of sealing the conductors, for an electron discharge tube.

Standard Telephones and Cables Ltd. and S. J. Powers. Application date 21st April, 1943.

These abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2. Price 1/- each.

ABSTRACTS AND REFERENCES

Compiled by the Radio Research Board and published by arrangement with the Department of Scientific and Industrial Research

Comparative Length of the Abstracts.—*It is explained to new readers that the length of an abstract is no sign, by itself, of the importance of the work concerned. An important paper in English may be dealt with by a short abstract, or even, if it is in a journal readily obtainable, by a square-bracketed addition to the title, while a paper of similar importance in a language other than English may be given a long abstract. In addition to these questions of language and accessibility, the nature of the work has, of course, a great effect on the useful length of its abstract.*

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PROPAGATION OF WAVES

703. On the Perturbation of a Problem of Proper Values by Modification of the Boundary : the Case of the Propagation of Electromagnetic Waves in Cylindrical Guides.—R. Courtel. (*Comptes Rendus* [Paris], 6th/27th Sept. 1943, Vol. 217, No. 10/13, pp. 261–263.)

" The theoretical researches on the propagation of decimetric and centimetric electromagnetic waves in cylindrical guides lead to a linking of the study of the stability of the waves (Brillouin, 873 of 1939) with the calculation of the perturbation of the proper values of the problem $\partial^2 u/\partial x^2 + \partial^2 u/\partial y^2 + \alpha^2 u = 0$ by a modification of the boundary, the conditions at the limits remaining the same, namely $u = 0$ for waves of electric type and $\partial u/\partial n = 0$ for those of magnetic type ; the propagation is represented by a Hertzian vector parallel to the generators, of value $\pi = u(x, y)e^{i(kct - k_z z)}$; the constant α^2 can take on only one discontinuous series of values each corresponding to a definite régime of propagation, in particular to a phase velocity $v_z = c(k/k_z)$ and a group velocity $g = c(k_z/k)$, both well defined (de Broglie's book, 3083 of 1944) ; we have $\alpha^2 = k^2 - k_z^2$ . . . Following a procedure frequently employed in this type of question, we may solve the problem as follows : we come back first to a modification of the condition a tthe limits without change of boundary C_0, thanks to a Taylor development of the function looked for in the neighbourhood of the new boundary C . . ." In this way, and by the use of a method similar to that employed in the theory of operator perturbations, the writer obtains his equations 4, 5, and 6.

He continues : " The examination of the particular case of guides of circular section leads to some interesting results which seem capable of practical applications", in connection with fluted or grooved guides possessing the well-known properties of a uniaxially anisotropic optical medium with respect to polarized waves propagated perpendicularly to the axis. In certain cases a suitable deformation will make the tube function as a polarizer, the $\cos m\theta$ component being completely arrested.

704. On Waves in Bent Pipes [Letter prompted by Riess's Work, 2840 of 1944, using the Perturbation Method].—S. A. Schelkunoff : Riess. (*Quart. Applied Math.* [Brown University], July 1944, Vol. 2, No. 2, pp. 171–172.)

" While it is true that in a bent pipe the waves cannot be classified into transverse electric and transverse magnetic types because in general both E and H have components in the direction of wave propagation, a different classification into two types [" electrically oriented," $EO_{m,n}$ wave type, and " magnetically oriented," $MO_{m,n}$ wave type] is possible. This permits another method, which yields the general solution in terms of Bessel functions . . ." For a bent pipe formed by the intersection of two concentric spheres and two coaxial cones emerging from the centre there is also a solution in terms of known (Bessel and Legendre) functions : these waves may be called " spherically oriented " to distinguish them from the previous, " plane oriented " waves : in the abbreviations, the EO and MO would, for this distinction, be preceded by S or P.

705. Propagation of Electromagnetic Waves in Branched Hollow-Pipe Lines.—E. M. Studenkov. (*Journ. of Phys.* [of USSR], No. 6, Vol. 7, 1943, p. 308 onwards.) A letter mentioned in *Review Scient. Instr.*, Oct. 1944.

706. Theory of Diffraction by Small Holes [with Application to Mutual Excitation of Cavities coupled by Small Holes, Radiation from Cavities, Effect of Gap in Wave-Guide, etc.].—H. A. Bethe. (*Phys. Review,*

1st/15th Oct. 1944, Vol. 66, No. 7/8, pp. 163–182.)

1.—The problem: the diffraction of electromagnetic waves by a small hole in an infinite plane conducting screen. 2.—The failure of Kirchhoff's Theory. 3.—Mathematical formulation of the problem. 4.—Solution: "the method is based on the use of fictitious magnetic charges and currents in the diffracting hole, which has the advantage of automatically satisfying the boundary conditions on the conducting screen. The charges and currents are adjusted so as to give the correct tangential magnetic, and normal electric, field in the hole . . ." 5.—Calculation of the diffracted field and total radiation.

6.—Discussion of the result: (a) comparison with the Kirchhoff solution: the results are entirely different. "Quite obviously, the polarisation of the radiation is different, because our solution satisfies the boundary condition while Kirchhoff's does not. Also the angular distribution of the total radiation is different. However, the most striking difference is in the absolute value of the field", the radiation through a small hole being very much smaller than indicated by Kirchhoff's theory: the E and H fields are reduced roughly in the ratio a/λ (where a is the radius of the hole) and the radiation intensity is thus reduced by a factor of the order of $(a/\lambda)^2$. (b) Representation by electric and magnetic dipoles. (c) Diffraction of a plane wave. (d) Comparison with Sommerfeld's solution. 7.—Field in and near the hole.

8.—Possible extensions of the theory: to holes comparable in size with the wavelength: to holes of various shapes: to screens and holes which are not plane (*e.g.* when the hole itself is "essentially curved", as in the case of a gap in a cylindrical wave-guide, where the gap itself is the surface of a short cylinder. "Such a problem will presumably require an entirely new solution, but it is likely that at least the same principle will work as in our case, and that the symmetry of the cylinder will be helpful for obtaining the solution"). 9 & 10.—Application to the theory of cavities coupled by small holes, leading to equations very similar to those for ordinary coupled circuits: "the phase and amplitude relations of two coupled cavities are not uniquely determined, but there are two modes of oscillation, of slightly different frequency, for which these relations are opposite." 11.—Stepping-up the excitation from one cavity to another by the asymmetrical coupling of two tuned cavities, or by the symmetrical (or asymmetrical) coupling of two slightly mistuned cavities.

707. "Fields and Waves in Modern Radio" [Book Review].—S. Ramo & J. R. Whinnery. (*Proc. I.R.E.*, Sept. 1944, Vol. 32, No. 9, p. 576.) An enthusiastic review.

708. On the Distribution of Electricity on Thin Unclosed Conducting Layers [by Method similar to That dealt with in 798 of 1939, 4469 of 1940, & 378 of 1942].—G. A. Grünberg. (*Journ. of Phys.* [of USSR], No. 3, Vol. 7, 1943, pp. 93–98: in English.) The Russian original was dealt with in 2957 of 1942.

709. "Theory of the Coastal Refraction of Electromagnetic Waves": Errata.—G. A. Grünberg. (*Journ. of Phys.* [of USSR], No. 2, Vol. 7, 1943, Inset at Beginning.) *See* 3386 of 1944.

710. "Radio Waves and the Ionosphere" [Book Review].—T. W. Bennington. (*Nature*, 30th Sept. 1944, Vol. 154, No. 3909, p. 413: *Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, p. 648.) *See* also 3330 of 1944.

711. Study of the D Region of the Ionosphere [by Recordings of Atmospherics].—Rivault. (*See* 731.)

712. Some Observations on the Behaviour of the E and F Layers to Broadcast-Wavelength Pulses.—De Witt & Ring. (In paper dealt with in 797, below.)

713. On the Experimental Investigation of Night-Time E Ion-Densities and Their Determination by the Application of Chapman's Formula.—M. M. Sen Gupta & S. K. Dutt. (*Indian Journ. of Phys.*, April 1944, Vol. 18, No. 2, pp. 88–96.)

"It is thus seen from our results, and also corroborated by the data obtained at Watheroo [at about the same latitude as Patna, the present point of observation, but in the opposite hemisphere], that Chapman's formula does not account wholly for the conditions of the ionosphere. This discrepancy may perhaps be due to the fact that the value of σ_0 has been taken to be constant throughout. It seems to us that during winter night-time recombination is less than in the summer nights. It may, therefore, be suggested that the value σ_0 cannot be taken to be the same during all hours both in summer and winter for the calculation of night-time E ion-densities in accordance with Chapman's formula."

714. An Observation on the Ionosphere during the Solar Eclipse of 20th July, 1944 [Behaviour of Amplitude of E-Layer Reflections].—C. K. Jen, K. T. Chow, Y. T. Lo, & C. C. Kuan. (*Phys. Review*, 1st/15th Oct. 1944, Vol. 66, No. 7/8, p. 226.)

Kunming observations on 3 Mc/s pulses, before, during, and after the day of the eclipse (partial at Kunming). "For this frequency only the E-layer reflections have been most consistently observed; the reflections from the F layer only begin to occur more prominently during late afternoons." As found by other workers, the virtual height of the E layer remained sensibly constant around 120 km, as much on the eclipse day as on any other day, but the record of the *amplitudes* of the reflected pulses on the eclipse day "is considered as remarkable in that it is very different from the usual pattern [which generally has a small peak just before noon but soon dies down thereafter and only begins to rise as the afternoon progresses] and its rise and fall are fairly coincident with the beginning and end of the eclipse.

"The general elevation of the reflected amplitude is most extraordinary [the higher of the two peaks reaches a value, compared with the ground-wave amplitude, of 0.75, whereas the average maximum for seven other days is about 0.25]. There is, further, a dip of amplitude [down to 0.5] strangely coincident with the maximum eclipse . . ." These results suggest a large decrease of absorption with respect to the E reflection during the eclipse: this may be due to changes in the E layer itself as the result of decreased ionisation, or may be caused by a lower absorbing layer. "One may

suppose that the rapid de-ionisation and recombination processes that may take place in this hypothetical layer may be responsible for the decreased absorption. The constancy of the virtual height of the E layer and the extraordinary increase of the reflection amplitude " seems to support the second hypothesis: but " the mysterious middle dip is surely not readily explainable on this exceedingly crude model, and there must be many other difficulties in explaining various other phenomena "; further studies of such amplitude variations seem to be needed before the matter can be cleared up.

715. " Über die Energiestrahlung der Sonne " [Book Review].—F. Leiri. (*Zeitschr. f. Fernmeldetech.*, 16th Oct. 1943, Vol. 24, No. 7, p. 108.)

A Helsingfors publication, following the novel lines laid down in the writer's previous works, particularly his 1940/41 book, " New Physics on the Foundations of the Classical ". The idea of a spherically symmetrical emission of solar energy is replaced by the picture of a discrete emission in definite directions: " heliocathodic radiation " is defined and explained: the rôle of " subelectrons " in solar protuberances is discussed: " a transformation of matter into energy, or the equivalence of matter and energy, embodies a contradiction and is to be rejected as a hypothesis."

716. The Magnetic Storms of 17th/20th September, 1941 [Report on Italian Observations, Magnetic, Ionospheric, Broadcasting, Naval, & Commercial].—(*Zeitschr. f. Fernmeldetech.*, 15th Jan. 1943, Vol. 24, No. 1, pp. 14–15: summary only.)

717. On the Extinction of Induction Currents in a Conducting Sphere: Geophysical Applications. — L. Cagniard. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 479–481.)

Lamb's classic solution is too complicated to be really applicable to particular problems—which is hardly surprising, in view of the difficulties inherent in the study of transient régimes and the added complications when spheres are involved. " It is known, for example, that important problems of mathematical physics, such as the propagation of seismic waves in the Globe or the diffraction of an electromagnetic wave by a sphere (rainbow, coronas, etc.), have as yet received solutions which do not completely satisfy the geophysicists. It would therefore be a notable advance if one succeeded in expressing the solution of problems of this type with the aid of formulae which, while remaining rigorously correct, would enable the numerical calculation to be made in practical fashion of all the circumstances of the phenomena . . ."

The writer's treatment, summarised in this Note, leads to support rather than to rejection of the idea that terrestrial magnetism can be attributed, for the greater part, to the existence of induced currents on their way to extinction: the conditions would be satisfied by an Earth 150 million years old, an original field of 25 gauss, and a non-magnetic core of radius 3500 km, with a conductivity 37 times as high as that of copper. But to be of real geophysical interest the calculations must be extended to a globe with rotational movement: if this can be done, the theory should cover the explanation of terrestrial magnetism, the displacements of the magnetic poles, secular variations, and earth currents.

718. Auroral Spectrum of the Nitrogen Molecule [New Results in the Investigations dealt with in 3786 of 1944 and Back References].—Renée Herman. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 492–494.)

The various contradictory results obtained by different workers are briefly reviewed, and the writer then describes the latest laboratory experiments and the conclusions reached. " There are, in reality, two different phosphorescences superposed: the first, that of Lord Rayleigh (rediscovered by Cario & Stille), composed of the α bands of the first positive system (selective excitation) and of the second positive group: the other composed of the first negative group and the first positive group, the latter without selective excitation but with a distribution of the band intensities corresponding to a very high temperature . . . To sum up, the spectrum of the 'green' phosphorescence of nitrogen is made up of all the systems found in the auroral emission, but with a distribution of intensities which is markedly displaced."

719. Identification of a New System of Bands of the Neutral Nitrogen Molecule [and a Comparison with the Night-Sky Spectrum]. —Renée Herman. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 561–562.) *See* also 718, above.

720. Contribution to the Study of the Emission Spectrum of Nitrogen [Effect of Progressive Reduction of Pressure: Table of Wavelengths of the New Bands degraded towards the Red, and Comparison with Calculations: etc.].—J. Janin. (*Comptes Rendus* [Paris], 4th/26th Oct. 1943, Vol. 217, No. 14/17, pp. 392–393.)

721. Influence of Air-Gases on the First and Second Positive Systems of Nitrogen [and the Similarity to the Effect given by Active Nitrogen: the Question of the Exact Rôle played by Foreign Gases].—N. R. Tawde & V. S. Patankar. (*Phil. Mag.*, Sept. 1944, Vol. 35, No. 248, pp. 600–605.)

722. On the Existence of Atomic Nitrogen in the Upper Atmosphere of the Earth.—Ta-You Wu. (*Phys. Review*, 1st/15th Aug. 1944, Vol. 66, No. 3/4, pp. 65–68.)

For previous work *see* 2846 of 1944. " It is shown that the absence of certain lines of N1 and the absence of continuous absorption which leads to the dissociation of N_2 cannot be considered conclusive evidence against the existence of atomic nitrogen. Relative densities of the E and F layers are discussed, and it is shown that observations of high density in the F layer may be compatible with the existence of atomic nitrogen. Possible transitions which produce the night-sky spectrum are discussed." *See* also 723, below.

723. A Strong Infra-Red Radiation from Molecular Nitrogen in the Night Sky.—J. Stebbins, A. E. Whitford, & P. Swings. (*Phys. Review*, 1st/15th Oct. 1944, Vol. 66, No. 7/8, pp. 225–226.)

Four years ago the first two writers found an

intense infra-red radiation from the night sky " which is scores of, if not a hundred, times as strong as the ordinary persistent auroral line at 5577 AU. That the new radiation must come from the atmosphere was shown by its variation with zenith distance, by its usual progressive decrease through the night, and by its variability from night to night and from season to season." On 20th July, 1944, " the radiation was doubly strong and was varying rapidly, as much as 10 or 15% in five minutes. No marked magnetic disturbance occurred on that night. It was then suggested by Swings that the radiation was undoubtedly molecular in origin and very likely could be traced to the (0,0) band of nitrogen at about 10450 AU . . ." The measured mean wavelength was found to be 10444 ± 10 AU.

" Failure to observe other strong N_2 bands indicates in the night sky a mechanism enhancing the (0,0) band relative to the other vibrational transitions. It is suggested that during the night N_2 molecules are brought in the level $v' = 0$ of the $B^3\pi_g$ state in three-body recombinations $N + N + N_2 \rightarrow N_2 + N_2^{exc}$. The nitrogen atoms would be formed during the day through photo-dissociation of N_2 by solar radiation . . . This mechanism, which is similar to that suggested by Chapman for the [OI] night-sky emission, implies the presence of a fairly large number of nitrogen atoms in the upper atmosphere. Although the photo-dissociation of N_2 by solar radiation is usually considered as very weak compared with that of O_2, it is by no means negligible", and in addition to Wu's recent arguments in favour of the presence of nitrogen atoms in the upper atmosphere (2846 of 1944 and 722, above), Dr. Herzberg reports that N_2 molecules can be predissociated by radiation of wavelength shorter than about $\lambda 1400$.

" The mechanism suggested here depends on the value $D(N_2) = 7.38$ v ; it would not be effective if the heat of dissociation $D(N_2) = 9.76$ v, recently suggested by A. G. Gaydon (2847/8 of 1944), were adopted."

724. Remarks on the Conditions of Excitation of the Forbidden Rays, and on the Frequency of Collisions in the Gaseous Nebulae.—J. Gauzit. (*Comptes Rendus* [Paris], 6th/27th Sept. 1943, Vol. 217, No. 10/13, pp. 289–291.)

725. On the Electrical Equilibrium of the Atmosphere.—L. Cagniard. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 570–572.)

In a calm atmosphere without large ions, diffusion being neglected, the stationary régime is represented by eqns. 1, 2, and 3 involving E (intensity of electric field), K, K' (mobilities of positive and negative ions), n, n' (number of ions per cm³), α (coefficient of recombination), q (number of ion pairs created per second per cm³), and z, the vertical height. Assuming K, K', α, and q to be constants, J. J. Thomson, and later Swann, studied this system of equations.

" It is of interest to take up the discussion again in the general conditions of the actual atmosphere, to deduce from it the variation of E, n, and n' as a function of z. It may be hoped that this theoretical law will represent approximately the average normal evolution of E, n, and n' in epochs of calm and at high altitudes, where the influence of the large ions is probably greatly reduced. I shall also show how the purely mathematical discussion of these equations throws light on the true nature of the physical problem of atmospheric electricity . . .", so that the geophysical phenomena are linked with the experimentally found laboratory phenomena (" electrode effect," etc.).

726. Electrical Equilibrium of an Ionised Atmosphere.—L. Cagniard. (*Ann. de Physique*, Jan./March 1944, Vol. 19, p. 71 onwards.) A 17-page paper, referred to in *Review Scient. Instr.*, Sept. 1944. *See* also 725, above.

727. The Measurement of the Correlations in Atmospheric Turbulence [Experimental Verification of Karman's, Euler's, & Kinematic Correlations by the Writer's Photoelectric Anemometer with Very Low Inertia, 1730 of 1938].—R. Faillettaz. (*Comptes Rendus* [Paris], 6th/27th Sept. 1943, Vol. 217, No. 10/13, pp. 281–283.)

728. " Meteorology, Theoretical and Applied " [Book Review].—E. W. Hewson & R. W Longley. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 265–266.)

729. Doppler Effect in a Refractive Medium [Case of a Vibrating Electric Dipole (Excited Atom)].—I. M. Frank. (*Journ. of Phys.* [of USSR], No. 2, Vol. 7, 1943, pp. 49–67 : in English.)

Author's summary :—" The value of the Doppler change of the frequency of light, emitted by a source moving in a medium, is determined by the ratio of the velocity of the emitting source to the velocity of light in the medium (for the Doppler frequency). A comparison with a light source moving in a vacuum shows the following peculiarities : (a) a motion with a velocity greater than the velocity of light for the Doppler frequency is possible, and (b) the connection between the frequency of the source and the Doppler frequency is not linear.

" In the first case, frequencies appear in the rays that satisfy the Doppler condition for velocities greater than that of light (in this case there must be, as a rule, not less than two such frequencies—the 'complex ' Doppler effect). Besides this, independently of the velocity of the source, there is always at least one frequency satisfying the Doppler condition for a velocity less than the velocity of light.

" The second peculiarity leads, in the case of a sufficiently large dispersion, to the possible excitation of the ' complex ' Doppler effect even for velocities much smaller than that of light. This effect can be observed experimentally in a gas possessing a sufficiently narrow absorption line. For a movement with a velocity greater than that of light an oscillator, in contradistinction to an electron, will not give radiation of Čerenkov type. This radiation is emitted if the dipole moment of the source has a constant component."

730. Note on Specular Densities and Forward Scattering [Interpretation of Pitt's Experi-

mental Results, leading to a General Rule which should hold in Other Fields of Physics]. —F. Urbach : F. H. G. Pitt. (*Journ. Opt. Soc. Am.*, Oct. 1944, Vol. 34, No. 10, pp. 592–594.)

The rule deduced is that " the forward scattering of an absorbing and slightly scattering layer reaches a maximum if the fraction of the incident beam, which is transmitted specularly, is just equal to $1/e$."

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

731. STUDY OF THE D REGION OF THE IONOSPHERE [by Recordings of Atmospherics]. — R. Rivault. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 494–496.)

If the distance d from source to receiver is over about 100 km, atmospherics show themselves in the form of a train of damped oscillations, generally 3 to 6 in number, of pseudo-periods increasing from about 100 μs for the first oscillation to 500 μs for the last, corresponding to frequencies of 10 000 and 2000 c/s. The oscillograms are often complicated by the deformation of the amplitude peaks or the appearance of new peaks. Laby & others (2184 of 1940) and Schonland & others (3063 of 1939) explain these anomalies as due to the superposition, on the atmospheric propagated by the direct path along the ground, of waves arising from successive reflections of the disturbance between ground and ionosphere. The virtual heights h of the reflecting region, deduced from the oscillograms, vary from 53 to 82 km : the reflections take place at the D region of the ionosphere, whose altitude, determined by other procedures, is about 70 km.

The direct exploration of the ionosphere requiring resources not always available, the writer decided to carry it out indirectly by a cathode-ray-oscillographic investigation of atmospherics, using the automatic sweep-release circuit referred to in 1730 of 1943 and outlined here. The beginning of the oscillogram, of amplitude below the (adjustable) threshold value at which the ray is released, is nevertheless recorded, thanks to the use of an artificial retarding line. The whole arrangement leads to economy in film and the possibility of a selection of the atmospherics recorded.

The time intervals separating the arrival of the different echoes due to the same disturbance are read on the oscillogram : they increase with the number of successive reflections and tend towards a limit equal to h/c, where c is the velocity of propagation, taken, as a first approximation, as equal to that of light. Nomograms were prepared permitting the quick determination of h and d from this distribution of the times.

Interpretation of the results is sometimes difficult, because the sources are usually multiple. Occasionally, however, there is only one isolated source : thus one July evening all the oscillograms obtained over half an hour showed multiple echoes which were particularly distinct and which agreed in giving (with a value for d between 340 and 380 km) the virtual height of the D region as 75 km, within 2 km. When there are several simultaneous sources, the mingled oscillograms can to a certain extent be separated out by adjusting the threshold of the sweep-release device. It was found that when the working-out (with the help of the nomograms) gave coherent values for d and h for one of the sources, the same thing applied to all the others ; but if, in spite of the amplitude and distinctness of the echoes, it was impossible to obtain plausible results, this was the case for all the sources, as if h were varying rapidly and irregularly. In this case the nomograms, constructed on the assumption of a flat D region, were no longer applicable.

Up to the present the multiple reflections have not been observed before sunset, only during the night hours. The number and amplitude of the successive echoes are not connected with the frequency and intensity of the atmospherics: it may happen that when, on the same oscillogram, two atmospherics are obtained which are comparable in amplitude and form, the one (generally the second) will be followed by up to twenty echoes of regularly decreasing amplitude, while the other has not a single reflection to follow it.

Finally, the recordings have brought out clearly the way in which the D region reacted to an important storm disturbance evidenced by a recrudescence of the general level of atmospherics. Over the eleven successive days in October which included the maximum activity of this disturbance, records were made at the beginning and end of each night. The value for h oscillated between 80 and 85 km at the beginning of the period, rose to 92 km during the night of maximum activity of the disturbance, fell to 74–75 km on the following night, and subsequently mounted again to 85–89 km.

The writer concludes : " In spite of the absence of records of other kinds, these results direct attention to a probable effect of certain large tropospheric discontinuities on the virtual height of the D region, a height showing a rapid undulation at the passage of the discontinuity."

732. ON THE ELECTRICAL EQUILIBRIUM OF THE ATMOSPHERE, *and* ELECTRICAL EQUILIBRIUM OF AN IONISED ATMOSPHERE.—Cagniard. (*See* 725 & 726.)

PROPERTIES OF CIRCUITS

733. " FIELDS AND WAVES IN MODERN RADIO " [Book Review].—Ramo & Whinnery. (*See* 707.)

734. USE OF FREQUENCY-CONVERSION DIAGRAMS [for the Comparison of Non-Linear Elements such as U.H.F. Diodes & Crystals].—Stockman. (*See* 778.)

735. THEORY OF DIFFRACTION BY SMALL HOLES [with Application to Cavities coupled by Holes, etc.].—Bethe. (*See* 706.)

736. COAXIAL-LINE DISCONTINUITIES [in Particular Connection with Lines used as Elements in Centimetric-Wave Cavity-Type Circuits].—J. R. Whinnery, H. W. Jamieson, & T. Eloise Robbins. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 695–709.)

In a recent paper (2125 of 1944) it was shown that effects from certain step-type discontinuities (such as changes in the diameter or diameters) can be calculated from an equivalent circuit in which the local waves excited at the change in section are accounted for by a lumped " discontinuity admittance " shunted between lines at the junction : ordinary transmission-line equations for the principal or transmission-line-type wave are used only

in the two lines on either side of the discontinuity.

The analysis and curves of numerical values for these "discontinuity admittances" were derived for a parallel-plane line, although rules were given for approximate application of the results to coaxial-line discontinuities. "It is the purpose of this paper to give curves calculated for coaxial lines directly, and the analysis leading to these curves. These curves not only supply more accurate values of discontinuity admittance for the coaxial-line problems than are obtainable from the parallel-plane transmission-line curves used with the approximate rules, but also provide the justification for those rules and the degree of approximation resulting from their use." If the frequency is low enough for the transverse dimensions to be a small fraction of the wavelength, the "discontinuity admittance" is found to be a pure capacitance. Curves are given of a frequency factor F showing the amount by which the discontinuity capacitance must be corrected as the transverse dimensions become comparable with the wavelength; also of a proximity factor P showing corrections to be applied if a short-circuiting disc termination is placed near the plane of the discontinuity.

737. THE IMPULSE RESPONSE OF ELECTRICAL NETWORKS, WITH SPECIAL REFERENCE TO THE USE OF ARTIFICIAL LINES IN NETWORK DESIGN.—M. Lévy. (*Elec. Communication*, No. 1, Vol. 22, 1944, pp. 40–55.) Reprint of the paper dealt with in 2153 [and *see* 2152] of 1944.

738. A NETWORK THEOREM [Derivation of Simple Equation relating the Impedance of a Two-Terminal Network made up of Low-Loss Reactances to the Reactance of the Same Network of Zero-Loss Reactances: Application to Short-Circuited Transmission-Line Sections, etc.].—N. I. Korman. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 710–712.)

The writer starts with eqn. 2 (due to Guillemin: *see* Appendix) relating the impedance $X = X(j\omega)$ of a two-terminal network of pure reactances to the impedance Z of a network identical with the first except that each inductor has losses representable by a series resistance $\omega L/Q_L$ and each capacitor has losses representable by a shunt resistance $Q_c/\omega C$. By expansion of the two radicals of eqn. 2 in power series, and of the reactance function X in a Taylor series about the point $j\omega$, he obtains eqn. 6 for Z; this, for regions well within the limits of convergence of the series, may be sritten as eqn. 7, composed of the original $X(j\omega)$ added to two real terms: showing that the effect of a small amount of dissipation on the impedance of a two-terminal reactive network is to add a resistive component without appreciably altering the reactance, except near frequencies of anti-resonance. Another simple equation (eqn. 10) gives the relation between the admittances. Among the examples given is the calculation (eqn. 14) of the parallel L-C-R circuit equivalent to a section of transmission line approximately an odd number of quarter-wavelengths in length and short-circuited at its far end.

739. GRAPHICAL SOLUTION OF VOLTAGE AND CURRENT DISTRIBUTION AND IMPEDANCE OF TRANSMISSION LINES.—R. C. Paine. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 686–695.)

Author's summary:—"On a radio transmission line with reflected waves, geometric construction is used to determine the voltage, current, and impedance at any required point for a known load of resistive or complex impedance. Unknown loads are determined by observation of standing waves and the use of geometric constructions. Charts are shown for the direct determination of voltage, current, and impedance vectors at all points on radio transmission lines for any load condition, for use in solving transmission problems." The characteristic impedance of the line is assumed to be pure resistance and the attenuation to be negligibly low: "these assumptions do not in general result in serious errors for ordinary radio transmission lines."

740. TRANSMISSION-LOSS CHARTS [for Losses or Gains due to the Introduction of a Series Impedance into a Line or of an Impedance shunted across the Line].—J. G. Roof. (*Electronics*, June 1944, Vol. 17, No. 6, pp. 130 and 132.)

741. COMPUTING CIRCUIT RESPONSE TO PULSES [by Method which is Mathematically Simpler, and gives Clearer Physical Picture, than Alternative Methods].—J. B. Trevor, Jr. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 122–124.)

The response at the end of the first cycle is first found, and the superposition theorem used to obtain that for following cycles. Expansion and solution of the general equations gives eqns. 14 and 15 for V_n, and by letting $n \to \infty$ eqns. 16 and 17 are obtained for V_∞, equivalent to the steady-state equations for sine-wave e.m.fs.

742. "THE SIMPLE CALCULATION OF ELECTRICAL TRANSIENTS" [Book Review].—G. W. Carter. (*Wireless Engineer*, Jan. 1945, Vol. 22, No. 256, pp. 15–16.) "Can be thoroughly recommended to those radio engineers who have occasion to analyse non-sinusoidally excited circuits."

743. INTRODUCTION TO FOUR-TERMINAL-NETWORK AND FILTER THEORY: PART I [concluded from 38 of 1944].—E. Hameister. (*Zeitschr. f. Fernmeldetech.*, 10th Sept. 1943, Vol. 24, No. 6, pp. 79–84.) For Part II *see* 2154 of 1944.

744. A NOTE ON A CERTAIN MULTIPLE INTEGRAL.—Gladwin. (*See* 939.)

745. COUPLING COEFFICIENT OF TUNED CIRCUITS [for All Ordinary Methods of Coupling: Simple & Unified Manner of Expression].—G. W. O. H. (*Wireless Engineer*, Jan. 1945, Vol. 22, No. 256, pp. 1–2.) Sequel to the editorial referred to in 2157 of 1944, prompted by a five-fold error in a recent text-book diagram.

746. A STABLE DIRECT-COUPLED AMPLIFIER [for Cathode-Ray-Tube Deflection, etc: Voltage Gain of 5000: Aperiodic Coupling Element (with Stabilising Triode) permits Response to Zero Frequency & to High Frequencies restricted only by Usual Limitations of *RC*

Coupling].—G. R. Mezger. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 106–110 and 352, 353.)

747. Improved High-Frequency Compensation for Wide-Band Amplifiers.—Bereskin. (*See* 847.)

748. Grounded-Grid Amplifiers [and the Signal/Noise Ratio: Letter prompted by 2883 & 3422 of 1944: the Assumption made in Each Paper that the Noise-Equivalent Resistance for a Valve used as Grounded-Grid Amplifier is the Same as when used in Conventional Circuit: Its Proof by Analysis taking Feedback into Account].—L. Katz. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, pp. 641–642.)

"Thus all conclusions drawn by Herold in his excellent paper [on u.h.f. receiver noise ratios: 1655 & 2336 of 1942] also apply to the grounded-grid amplifier." *See* also 750, below.

749. Reduction of the Effect of Spontaneous Fluctuations in Amplifiers for Metric and Decimetric Waves.—M. J. O. Strutt & A. van der Ziel. (*Physica*, Vol. 9, 1942, p. 1003 onwards: and *cf.* Vol. 8, 1941, p. 1 onwards [750, below].)

For a long summary, in German, see *Bull. Assoc. Suisse des Élec.*, 12th July 1944, Vol. 35, No. 14, pp. 381–383. "In short-wave working it is found that these small variations of the electron flow [due to shot effect and thermal agitation] produce, by induction, voltage fluctuations at the control grid which result in a magnification of the total fluctuation at the output. It will be shown here how the total fluctuation can be reduced considerably by an appropriate design of the amplifier circuit. For the following calculations it is assumed that only so small a frequency interval in the whole fluctuation spectrum is considered, that the impedances of the amplifier circuit may be regarded as constant over that interval. In such a narrow interval it is permissible, also, to treat the fluctuations as sinusoidal currents and voltages." The calculation is based on a triode working in short-circuit, with its control grid connected to the secondary terminal of a transformer, of ratio t, whose primary is supplied by the signal-producing source of internal resistance R_a: the signal (U_a) itself already contains spontaneous fluctuations u_a. The equivalent diagram of the input circuit of this first amplifier stage is shown in Fig. 1; the capacitance C (which may be negative, *i.e.* an inductance) represents a deliberate detuning.

The total fluctuation current in the output circuit, $\overline{i_g^2}$, is given by eqn. 6: this includes the direct shot-effect current and the currents induced by the voltage fluctuations at the control grid, but *not* the thermal-fluctuation current of the oscillatory circuit, since in short-wave working it is always possible to make R_{kr} so high that i_{kr} can be neglected (eqn. 3). The ratio of this total fluctuation current to the signal current, at the output, is thus given by eqn. 7a, which may be written in the simple form shown in eqn. 7b. The second term of the denominator in this last expression contains the factor w, defined by eqn. 8a. If the phase angle between anode current and grid voltage, which makes its appearance in short-wave working owing to the finite electron path-time, is denoted by ϕ_a, that between the shot-effect anode current i_0 and the cathode-lead fluctuation current i_k by ϕ_r, and that between the induced-fluctuation current i_g and i_k by $\phi_g - \pi/2$, then the expression for w becomes as in eqn. 8b.

It is obvious from eqn. 7b that to obtain the best value for the fluctuation-current/signal-current ratio there given, this quantity w must be made as small as possible: thus for $w = 0$ the first amplifier stage would contribute nothing to the noise level. What is wanted, therefore, is to select such values of t and C that w is a minimum. Putting $|i_0/i_g SR_g| = a$, $R_g/t^2R_a = x$, $\phi_a + \phi_g - \phi_r = \phi$, and $\omega CR_g = y$, then the conditions for minimum w are two: $ay = \cos\phi$ and $ax = \pm(a - \sin\phi)$. Since, from their definitions, x and a must always be positive, the plus sign in this second condition is applicable when $a - \sin\phi > 0$, and the minus sign when $a - \sin\phi < 0$. Two cases must therefore be distinguished (a third, where $a - \sin\phi = 0$, and hence $x = 0$, is of no physical interest): namely (1) where $a - \sin\phi > 0$, in which event $w_{min} = 4a(a - \sin\phi)$; and (2) where $a - \sin\phi < 0$, in which event $w_{min} = 0$, so that the shot effect of the valve is completely eliminated.

The graphical representation of case (1), given by the dotted curves of Fig. 2, shows that for increasing ϕ and decreasing a^2 a considerable reduction of w_{min} can be obtained: but zero value is only reached when the condition of case (2) is fulfilled. If the device of detuning is dispensed with (*i.e.* if $C = 0$, and consequently $y = 0$), w becomes a minimum when $a^2x^2 = (1 - 2a\sin\phi + a^2)$, in which case $w_{min} = 2a\{(1 - 2a\sin\phi + a^2)^{\frac{1}{2}} + (a - \sin\phi)\}$. In the special case $\sin\phi = 1$ it is possible, with a less than or equal to unity, to bring w_{min} down to zero even in these conditions of no detuning. The full-line curves of Fig. 2 give w_{min} as a function of a^2, with ϕ as parameter: they show that for large values of ϕ (easily obtained in the decimetric-wave region) very small values of w_{min} can be obtained without the use of detuning.

The actual values of a and ϕ which will give, according to the above equations, the optimum values of the detuning capacitance (or inductance) C and of the transformation ratio t, "can be obtained by measurements or calculated on data provided by models." The final paragraph of the summary deals with the objections to the detuning plan, both as regards the diminution of the amplification and the production of phase distortions. A suitable retroactive coupling will help, but the practical carrying out of the required retroaction is not always simple, for various conditions must be observed. However, "it is possible, according to Strutt & van der Ziel, to fulfil all these conditions and thus to construct amplifier stages in the metric- and decimetric-wave bands which will add practically no further fluctuations to the signal". For other recent work by the same writers *see* 1075, 1102, 2088/9, & 2362 of 1943 and 1177 of 1944.

750. Methods of Compensating the Effects of Various Kinds of Shot Noise in Electron Tubes and Attached Circuits.—M. J. O. Strutt & A. van der Ziel. (*Physica*, Jan. 1941, Vol. 8, No. 1, p. 1 onwards.)

This 22-page paper is mentioned in 748, above, as including the application, to the circuit analysis of noise, of the method commonly used in optics when a non-monochromatic beam of light is subject

to interference: "to obtain the total noise power, we finally integrate the squares of the magnitudes of these noise currents [taken in a small frequency-interval which is allowed to become infinitesimally narrow] over all frequencies."

751. THE NOISE OF THERMIONIC VALVES AND ITS INFLUENCE ON THE NOISE OF A CIRCUIT.—Engbert. (*See* 816.)

752. MEASUREMENT OF BACKGROUND NOISE BY THERMOCOUPLE AND BY A RECTIFIER-TYPE METER.—Baurand & Vallantin. (*See* 856.)

753. THERMAL NOISE IN A PARALLEL *RC* CIRCUIT [such as Crystal or Condenser Microphone Input Circuit to Amplifier: F. C. Williams's Formula & Its Application, leading to Chart giving Fluctuation Microvolts for Any Desired Band-Width & for Entire Frequency Spectrum].—C. J. Merchant. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 143–144.)

754. REDUCTION OF SPONTANEOUS FLUCTUATIONS IN VACUUM-TUBE ELECTROMETER CIRCUITS THROUGH MECHANICAL CONVERSION.—den Hartog & Muller. (*See* 858.)

755. VOLTAGE FLUCTUATIONS IN SEMICONDUCTORS.—B. Davydov & B. Gurevich. (*Journ. of Phys.* [of USSR], No. 3, Vol. 7, 1943, pp. 138–140: in English.) The Russian original was dealt with in 768 of 1944.

756. A NOTE ON ELECTRONIC NEGATIVE RESISTORS [and, in Particular, the Advantages of the Degenerated Amplifier with Input & Output Circuits coupled].—J. R. Tillman. (*Wireless Engineer*, Jan. 1945, Vol. 22, No. 256, pp. 17–24.)

The voltage-controlled type has received most attention recently, largely because of its many useful applications. "But the published data for these electronic 'negative resistances' are still incomplete or inaccurate in several respects. Modified dynatrons and modified transitrons have received little attention; the negative resistor produced by suitably coupling the input and output circuits of a highly degenerated amplifier has been neglected outside the U.S.A., and the erroneous impressions given by Chakravarti have remained uncorrected. This note is intended to clarify some aspects of the subject and to draw attention to those others on which further work is needed."

It is concluded that only the negative-feedback amplifier, with input and output circuits coupled, should be used for *precision* negative resistances. "Its disadvantages, the use of two (more, if it is to be suitable for use at very high frequencies) valves instead of one, and unsuitability at and near zero frequency, are for this, and many other purposes, unimportant."

757. LETTER ON "CATHODE-COUPLED OSCILLATORS" [32 of January: the Earthed-Grid Circuit, for which Several Advantages are claimed, is only That of a "Tapped-Coil Hartley": the Particular Earth Connection has No Effect on the Operation: etc.].—M. Felix: Butler. (*Wireless Engineer*, Jan. 1945, Vol. 22, No. 256, p. 14.) Actually, an alternative earth connection, giving the "cathode-tap Hartley", has a practical advantage.

758. NOTES ON THE STABILITY OF LINEAR NETWORKS [and the Extension of Nyquist's Criterion].—En-Lung Chu. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, pp. 630–637.)

To make a clear cut between mathematical analysis and the physical realisation of the conditions involved, the problem is posed mathematically as follows:—Given a network which can be described by a system of linear differential equations, it is desired to find a simple rule for determining whether, in the absence of applied forces (voltages or currents), the solution or solutions of these equations contain any term which, with increasing time, does not approach zero as a limit.

Nyquist's criterion is limited by the restrictions that the system should be unilateral and that the transfer factor, by which the amplifier and feedback circuit modify the current in one round trip, should approach zero when the frequency approaches infinity. Hurwitz's rule is more general, but his process may become quite involved, if not impractical, when the number of degrees of freedom is large. Llewellyn, in his paper on valve behaviour at ultra-high frequencies, gave a rule extending Nyquist's criterion to bilateral circuits, but "he took the rule on faith with neither proof nor the proper restrictions."

The present paper shows that the second restriction of Nyquist's criterion may be replaced by a less stringent one which makes the criterion more convenient for certain networks such as those with lumped constants, which often do not satisfy the original condition. Llewellyn's rule is verified and found to apply to any linear network, unilateral or bilateral, which is stable either in open-circuited or in short-circuited condition: "it is the one most general and simple extension of Nyquist's criterion from which other methods of extension can be easily justified." Finally, it is shown that with slight modification the rule can be applied to the impulsive networks which, though not physically realisable, are often met with in practical calculations where certain approximations (such as the assumption of lumped constants) have been made.

759. A THEOREM ON THE ENERGY STORED IN A REACTIVE TWO-POLE [leading to a Simplification of the Energy Calculations connected with the Establishment of Oscillations in Systems containing Complicated Oscillatory Networks].—B. N. [V. N.] Kessenich. (*Journ. of Phys.* [of USSR], No. 1, Vol. 7, 1943, pp. 37–41: in English.)

A detailed and rigorous proof of the theorem outlined in a previous paper (816 of 1944 & back reference): "the energy involved in a transient, resulting in a reactive two-pole from the switching-off of a sinusoidal e.m.f., does not depend on the spectral distribution in the transient, and is wholly determined by the two-pole reactance and its derivative, with respect to the frequency, at the operating frequency of the stationary state."

760. JUNCTION ANALYSIS IN VACUUM-TUBE CIRCUITS.—J. W. Miles. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, pp. 617–620.)

"The fact that the analysis of a circuit may be made in terms of its junctions as well as its meshes has been expounded by a number of men in different

fields (refs. "1" to "4"); nevertheless this approach does not appear to be sufficiently appreciated . . ." The writer shows that "the representation of a vacuum tube by a current generator in parallel with the plate impedances, and the solution of the equivalent circuit in terms of its junction voltages, generally leads to a simpler solution than the conventional mesh-current approach [for instance, there are fewer junctions than meshes]. The only important cases where this may not be true are in transformer-coupled amplifiers.

"A unique feature of the junction analysis allows vacuum tubes to be represented as passive networks composed of a bilinear self-impedance and a *unilinear* mutual impedance." The method of junction analysis is also advantageous in circuits arising from electro-mechanical analogies.

761. AIDS IN THE DESIGN OF INTERMEDIATE-FREQUENCY SYSTEMS.—Gardiner & Maynard. (*See* 781.)

762. POWER EFFICIENCY IN NON-LINEAR TRANSMISSION SYSTEMS [with Valves operating as Class B or Class C Amplifiers].—Stockman. (*See* 820.)

763. CORRESPONDENCE ON "THE VALIDITY OF THE EQUIVALENT-PLATE-CIRCUIT 'THEOREM' FOR POWER CALCULATIONS."—Preisman: Stockman. (*See* 819.)

764. POWER-FACTOR CORRECTION CHARTS [with Practical Data on Use of Capacitors & Auto-Transformers for Correcting Purposes, and on Effects of Harmonics].—H. Holubow. (*Electronics*, May 1944, Vol. 17, No. 5, pp. 143–144.)

765. GRID CONTROL OF GAS-FILLED TUBES [Typical Phase-Shifting Circuits for Smooth Control of Thyratrons & Ignitrons].—W. D. Cockrell. (*Electronics*, June 1944, Vol. 17, No. 6, pp. 124–128.) Some new symbols recommended by A.S.A. committees are tried out in the diagrams of this article.

766. CONSTANT-VOLTAGE PHASE ADJUSTER, WITH SINGLE-KNOB ADJUSTMENT [based on the Properties of Sinusoidal Three-Phase Quantities and the "Equilateral Triangle" Diagram: Continuous Adjustment 0°–360°: replacing the Rotating-Field Type: for Thyratron Control, C.R. Time Bases, etc.].—R. Dehors. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 524–526.)

767. "DIRECT-CURRENT CIRCUITS" [Book Review].—E. M. Morecock. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, p. 717.)

768. ON FOUCAULT CURRENTS IN AN ELLIPSOID OF REVOLUTION [Preliminary to the Work dealt with in 2639 of 1944].—M. Jouguet. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 523–524.)

769. EFFECT OF A SPHERICAL SCREEN UPON AN INDUCTOR.—C. F. Davidson & J. C. Simmonds. (*Wireless Engineer*, Jan. 1945, Vol. 22, No. 256, pp. 2–5.)

The change in impedance of an inductor, consisting of almost coincident circular loops, due to the presence of a spherical screen has been calculated, and curves are given which enable the increase in resistance and decrease in inductance to be computed relatively easily. "From the curves it is seen that when the ratio of the diameter of the loops to the diameter of the sphere is not greater than about 0.5, much simpler expressions may be used with an error of only a few per cent. These simpler expressions have previously been given by Kaden (Abstracts, 1933, p. 576; also 1934, p. 334 [and 571]) and, in effect, assume that the inductor may be replaced by a magnetic dipole of the same magnetic moment." The method of the present paper could be applied to the more general case in which the loops are not almost coincident, as assumed above, but are spaced along the z axis.

770. THE CALCULATION OF THE MUTUAL INDUCTANCE OF CIRCULAR FILAMENTS IN ANY DESIRED POSITIONS.—F. W. Grover. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, pp. 620–629.)

The case of *coaxial* circular filaments has been treated quite thoroughly by various writers, and an accuracy exceeding anything required in practice is possible: tables exist which make routine calculations quite simple and rapid. Calculations for more general cases, on the other hand, have received comparatively little attention, and existing formulae are slowly convergent, are useful for rather limited ranges of the parameters, and fail completely in other cases. Further, numerical computations are laborious.

The present paper sets out to provide methods and material suitable for routine calculations of an accuracy sufficient for practical purposes. Tables are calculated for the more important special cases (such as would apply to the design of a variometer with coils having eccentric axes and of one composed of two coils of small cross-sections: "equal circles with parallel axes" and "nearly equal circles with inclined axes which intersect at the centre of one of the circles", respectively). Tables to cover all possible cases of inclined circles and unequal circles with parallel axes would be very unwieldy, would take a vast amount of calculation for their preparation, and would leave other more general cases unprovided for. The writer therefore gives a general method for making routine calculations in *any* case, with results accurate to a few parts in a thousand—sufficiently good for most practical work—and obtained without excessive labour.

771. THE COMPUTATION OF MAGNETIC FIELD STRENGTH OF ROUND COILS OF SMALL CROSS-SECTION.—H. B. Dwight & G. O. Peters. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, Transactions pp. 684–685.) A summary was dealt with in 3443 of 1944.

772. ON THE TEMPERATURE COEFFICIENT OF AIR-CORED SELF-INDUCTANCES.—Bloch. (*See* 862.)

TRANSMISSION

773. ON PLASMA TRANSIT-TIME OSCILLATIONS.—W. O. Schumann. (*Zeitschr. f. Phys.*, 10th May 1943, Vol. 121, No. 1/2, pp. 7–33.)

Following on the paper dealt with in 2685 of 1941 [*see* also 680 of 1942: 157 & 2980 of 1943: 785/6 & 1944 of 1944: and 58/59 of January]. Author's summary:—"The electron and ion oscillations

occurring in plasmas, but also, under certain conditions, in high vacuum, are investigated as to their self-exciting action, taking the transit-time effects into account. It is found that in the large majority of cases the translation velocity of the particles has to be considered for the proper understanding of the self-excitation processes."

774. LETTER ON "PHASE-SHIFT OSCILLATORS" [2161 of 1941].—Blanchard: Ginzton & Hollingsworth. (*See* 843.)

RECEPTION

775. GROUNDED-GRID AMPLIFIERS [and the Signal/Noise Ratio].—Katz. (*See* 748.)

776. SENSITIVITY CALIBRATION OF RECEIVERS: A RADIATION METHOD FOR WAVELENGTHS BELOW 10 METRES.—J. S. McPetrie, W. E. Perry, & L. H. Ford. (*Wireless Engineer*, Jan. 1945, Vol. 22, No. 256, pp. 6–13.)

One of the several forms in which the sensitivity of a receiver can be expressed is the signal, having a stated percentage modulation, required at the input terminals in order to obtain a standard a.f. power output. From this, however, the weakest signal for satisfactory reception cannot be derived, since the noise produced by the set itself has not been taken into account. This difficulty can be overcome by expressing the sensitivity as the input signal necessary to give an output equal to (or a specified number of decibels greater than) the set noise. Lastly, the user of the receiver is often more interested in the field strength at the aerial, in μv/m, necessary to give a specified output, rather than in the microvolts at the input terminals which would give that output. At the wavelengths here in question, the measurement of sensitivity in this form is comparatively simple.

Authors' summary:—"The paper describes a radiation method of calibrating the sensitivity of short-wave receivers in the wavelength range of 0.5 to 10 metres in terms of the field strength at the aerial necessary to give an output signal which is just detectable through the background noise of the receiver. Three methods of general application are given, by which apparatus may be disposed so that the field at a receiving aerial, due to the current in a transmitting aerial, can readily be calculated. Transmitters which have been used for calibrating receivers are described." The accuracy ($\pm$ 2 db) is ample for all ordinary purposes, and the whole process takes place in exactly the conditions in which the receiving system will be used in practice, which is not generally the case with other methods of calibration.

777. U.H.F. CONVERTERS AND CONVERSION DIAGRAMS.—H. Stockman. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 281: summary of Nat. Electronics Conference paper.) *See* also 778, below.

778. USE OF FREQUENCY-CONVERSION DIAGRAMS [particularly for the Comparison of Non-Linear Elements such as U.H.F. Diodes & Crystals].—H. Stockman. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 679–686.)

"The mathematical difficulties involved in analytical treatment of single-mesh mixer circuits with diodes and crystals lead us to consider other methods for the determination of important mixer characteristics. This paper briefly reviews the rectification-diagram method as applied to large-signal detectors, and presents for consideration the Chaffee conversion-diagram method, which treats mixer circuits in the same way as large-signal detector circuits (Chaffee's book, 1933 Abstracts, p. 506). To demonstrate this method, the rectification diagram for a large-signal detector is used to illustrate conditions when two voltages of different frequencies are applied to the non-linear element; and it is shown how this rectification diagram may be given a more suitable form, describing the frequency-conversion properties of the non-linear element . . ."

The conversion diagrams may be obtained from practical measurements; the measuring circuits used to investigate the possibilities of the method are described, and the diagrams obtained for u.h.f. diodes and crystals are reproduced. Characteristics not given directly by the conversion diagrams can be derived in the form of contours read off from sets of the diagrams. "The information made available in this non-mathematical way *refers to the non-linear element plus i.f. load* and not to the frequency-conversion circuit with all its additional design problems": hence the special suitability of the method for the purposes described. For previous work by the same writer *see* 1522 & 3166 of 1944.

779. SUPER-REGENERATION: SOME UNUSUAL APPLICATIONS OF THIS SENSITIVE METHOD OF RECEPTION [Survey, including the "Squegging" Oscillator (as Transreceiver Circuit, Time Base, etc.): the "Super-infragenator": the Use of the Super-Regenerator to give an Expanded "Single-Span" Effect & an Emergency-Interrupting Action: for Duplex (& "Conference") Telephony: as Wide-Range Logarithmic Voltmeter: for Automatic Relaying: etc.].—O. J. Russell. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, pp. 361–364.)

780. SYNCHRONISED OSCILLATORS AS FREQUENCY-MODULATION RECEIVER LIMITERS.—C. W. Carnahan & H. P. Kalmus. (*Electronics*, Aug. 1944, Vol. 17, No. 8, pp. 108–111 and 332..342.)

"An oscillator stage following the i.f. amplifier and synchronised to a subharmonic of the i.f. signal gives voltage gain, adjacent-channel selectivity, quieting sensitivity, and good amplitude-limiting action. Synchronising voltage can be injected in several ways."

781. AIDS IN THE DESIGN OF INTERMEDIATE-FREQUENCY SYSTEMS [Design Chart for Prediction of Over-All Selective Performance of Coupled-Circuit I.F. Amplifiers: and a Rapid-Approximation Method of obtaining the Over-All Curve in Cases where Circuits of Different Coupling are Cascaded].—P. C. Gardiner & J. E. Maynard. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 674–678.)

"A general inspection of the chart will reveal some conclusions of interest. In most applications the shape factor [ratio of frequency deviations, B/A (Fig. 1), on the basis of the "generally accepted" 60 db unwanted-signal attenuation and

6 db variation-level for wanted signal] will fall between 2½ and 5. Further improvement in shape factor becomes increasingly more difficult of attainment as the number of circuits used increases. Beyond 8 or 10 circuits, improvement in shape factor is very expensive in terms of circuits required. Increased coupling to more than 25% over critical is not very effective in improving shape factor. Shape factors using a permissible amount of over-coupling attain a figure approximately half that obtained by cascading the same number of circuits singly ($C = 0$). Over-coupling of an amount in the region of 125% critical is usually quite acceptable; a pair of circuits coupled at $C = 1.25$ will produce a response curve with 2.5% rise at the double peaks ($U = 0.975$)": here U is the attenuation through the circuits (unity at resonance frequency) and is given by eqn. 4, taken from the second writer's paper on tuned transformers, 416 & 1155 of 1944.

782. Interference from Radio-Frequency Heaters: Suggestions for Control.—F. Youle. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, pp. 374–375.) For a leading article *see* p. 353.

783. Reducing Electrical Interference from Spectrographic Spark Source.—E. W. Landen. (*Journ. Opt. Soc. Am.*, Sept. 1944, Vol. 34, No. 9, p. 532.)

784. Wiring Noises [and the Much Worse Dangers of the Awful Wiring of Many Lighting & Power Circuits].—"Diallist." (*Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 367.)

785. H.F. Incremental Permeability Tuning [Measurements on Dust Cores: Development of Closed-Type Magnetic Circuit for Reduced H.F. Losses: specially suitable for Remote Control].—W. J. Polydoroff. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 280: summary of Nat. Electronics Conference paper.)

786. Radio-Frequency Volume Expansion [Suggested Alternative to Recent Volume-Expansion Methods all altering Gain of A.F. Amplifier].—C. R. Cosens. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 381.)

787. 8 000 000 New Broadcast Sets: What should They be Like?—R. W. Hallows. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, pp. 358–360.) For a leading article on this, and on the danger of excessive "Post-War Austerity" in the Wireless Industry, *see* p. 353: and *cf.* "Diallist", pp. 367–368.

788. Japanese Airborne Radio: the Model 99, Type 3 Receiver.—(*Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 373.)

789. Contribution to the Theory of the "Chopper" Transformer [Transformer of Car-Radio Vibrator-Type Converter: Calculation (on Assumption of Square-Wave Form) of R.M.S. Value of Current through Transformer Winding: Formula for Size of Wire: Calculation of Ripple in the Rectified Output (Much Less than with Mains Rectifiers)].—H. Kiderlen. (*Zeitschr. f. tech. Phys.*, Jan. 1943, Vol. 24, No. 1, pp. 15–17.)

AERIALS AND AERIAL SYSTEMS

790. Antennae for Ultra-High Frequencies: Wide-Band Antennae.—L. Brillouin. (*Elec. Communication*, No. 1, Vol. 22, 1944, pp. 11–39.)

Conclusion of the critical study dealt with in 2558 of 1944. The writer summarises the main results as follows:—"Reliable theoretical results have been obtained by different authors for spherical and spheroidal antennae fed across the equator (see sections 5 & 6). Reliable also are the computations for fine biconical antennae (sections 17 & 18).

"Less reliable theoretical data are those for fine cylindrical antennae. The computations of R. King should be corrected (see sections 15 & 16) after which they certainly could yield excellent results. Schelkunoff's theory of the cylindrical antenna does not seem very reliable, but the results apparently agree with experimental data (section 18).

"Many problems remain to be studied, especially of broad-band antennae. The most important ones would be:—The thick cylindrical antenna, including the effect of end surfaces: the spherical or spheroidal antenna fed across a finite gap near the equator, or combined with a biconical feeder (this last problem has been treated, approximately, by Schelkunoff): the directivity of the preceding types of antenna is not exactly known—polar diagrams of radiation could be drawn from the theory, but this phase of the problem has not been completed, at least in published papers.

"A general remark must be added: of the antenna shapes discussed fully, not one really possesses sharp edges or sharp points. Despite statements made by authors, the theory actually applies to antenna with rounded ends. The present author would suggest that any shape with sharp edges or sharp points should lead to narrow bands. Hence broad-band antennae should not only be *thick* antennae (a well-known result) but also *rounded* in their shape, *i.e.* rather streamlined. A rigid proof of this recommendation can hardly be given at present."

791. Sums of Series of the Form

$$\sum_{0}^{\infty} a_n J_{n+a}(z) J_{n+}(z).$$

—S. O. Rice. (*Phil. Mag.*, Oct. 1944, Vol. 35, No. 249, pp. 686–693.)

Schelkunoff (1049 of 1942 [for recent work *see* 612 of February]) expressed certain quantities associated with the impedance of an aerial as an infinite series involving Bessel functions: he also showed that a different physical argument leads to expressions involving Ci and Si functions for these same quantities. The present writer sketches a method of going directly from the series to the closed expression without appealing to the physics of the problem. Additional results, obtained in the search for the method, are also stated.

792. A Theorem on the Energy stored in a Reactive Two-Pole.—Kessenich. (*See* 759.)

793. "Fields and Waves in Modern Radio" [Book Review].—Ramo & Whinnery. (*See* 707.)

794. Graphical Solution of Voltage and Current Distribution and Impedance of Transmission Lines, *and* Coaxial-Line Discontinuities.—Paine : Whinnery & others. (*See* 739 & 736.)

795. Loop Antennae as Receiving Antennae.—J. Müller-Strobel & J. Patry. (*Helvet. Phys. Acta*, June 1944, Vol. 17, p. 159 onwards.) A 9-page paper mentioned in *Review Scient. Instr.*, Oct. 1944.

796. Antenna Design for Field-Strength Gain.—Kohler. (*See* 824.)

797. Significant Radiation from Directional Antennas of Broadcast Stations for determining Sky-Wave Interference at Short Distances [and a Required Modification to the F.C.C. " Standards "].—J. H. De Witt, Jr., & A. D. Ring. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 668–673.)

It is true that the F.C.C. require the engineer, in designing directional aerials, to " consider all of the appropriate vertical vectors " ; but consulting engineers in general have apparently thought it necessary to consider only the radiation at one angle above the earth, corresponding to that of a single reflection from the E layer, generally taken as at a height of 110 km.

From the authors' summary :—" Measurements indicating the length of the path of sky-wave signals received at short distances show that the signals take various paths and are not confined to a single path. Measurements were made, by pulse transmissions, of the relative time required for sky-wave signals to arrive at a receiving point some 230 miles from the transmitter. Control was had of the vertical radiation pattern. The records made of the received signal indicate varying heights and conditions of the reflection layer. To assure that no interference is caused by sky-wave signals, in accordance with the Commission's Standards of Good Engineering Practice, the Standards must be modified to require proper consideration of the radiation at all angles which constitute the ' appropriate vertical vector '."

The writers conclude that " to assure protection from interference, as would be afforded from an antenna with the vertical distribution of a 0.311λ antenna [the average height of the aerials in the measurements on which the F.C.C. decisions were based], the signal must not greatly exceed the value in the vertical plane for a comparable antenna in the horizontal plane. Whether the signal arrives by substantially different bearing routes has not been established, but there are definite indications that the signal computed for one bearing toward another station on the channel does not establish the interfering signal on that bearing . . ."

On certain occasions the writers were convinced that reflection took place at the F layer (pp. 671–672). They point out that nearly all the existing measurements on the E layer show its critical frequency only for daytime conditions : Gilliland & others have pointed out that the critical frequency " rose rapidly at sunrise out of the broadcast band . . . " From this it appears that penetration of the E layer by broadcast waves at night " may be a rather common occurrence. This would especially be true at the high-frequency end of the broadcast band and at small angles of incidence. It would be highly desirable for someone to undertake a complete study of the characteristics of the ionosphere in the broadcast band . . ."

798. Calculating Antenna Radiation Patterns [Relative Field-Strength Patterns in Horizontal Plane : Graphical Method using the " Linear Phasing Scale " in conjunction with the " Tangential Polar Graph "].—R. W. Cronshey. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, pp. 331–334.)

" Only two mechanical methods for calculating the field patterns have been described in technical journals (419 & 420 of 1943) at the writing of this paper. These greatly simplify the labour involved, for they draw the completed field pattern. This carries the simplification to the extreme. However, the maximum number of antenna elements which either of the machines will handle is three. Problems dealing with antenna arrays involving a larger number of elements simply cannot be solved by these machines. It is seen, therefore, that some simpler method is required, especially for arrays with a larger number of elements . . ."

With the two simple tools here described, " the student and the engineer will be capable of solving the most intricate field-form problems, involving up to an almost infinite number of antenna elements, in a minimum of time and with a minimum amount of effort." Using the scale and graph actually constructed, the accuracy obtainable was found to be such that the value of the sine and cosine terms could be read to two significant figures, and often (at one end of the scale) to three. The accuracy could probably be increased by increasing the sizes. Both scale and graph can be used again and again.

799. Phasing Networks for Broadcast Arrays [Vector-Synthesis (by Combined Graphical & Mechanical Technique) results in Economy of Circuit Components & Simplified Design Procedure, compared with Conventional Network Analysis].—C. R. Cox. (*Electronics*, June 1944, Vol. 17, No. 6, pp. 120–123.)

800. Antenna Power Divider [for Two-Element Broadcast Array : Chart for Values of L & C giving Any Required Division of Currents, with Constant Phase Shift & Constant Resistive Input]. — E. Travis. (*Electronics*, July 1944, Vol. 17, No. 7, p. 131.)

801. Modern Insulation of Transmitting Aerials [of High-Power Transmitting Stations : Recent German & American Developments in Stay & Mast-Foot Insulators in Steatite, Frequenta, Calit, etc : Calculation of Requirements].—A. Strauss. (*Zeitschr. f. Fernmeldetech.*, 16th Nov. 1942, Vol. 23, No. 11, pp. 161–168.) Already referred to in 108 of 1944.

VALVES AND THERMIONICS

802. Kinematics of Reflection Oscillators [Basic Theory of Electron Bunching in the Double-Resonator Klystron : Extension of Analysis to the Single-Cavity " Reflex Klystron " : the Use of the Applegate Diagram & Its Modification for the Latter

Case].—A. E. Harrison. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, pp. 709–711.) From the Sperry Gyroscope Company.

803. The Improvement of Valves for Ultra-Short Waves [Telefunken Developments].—W. Kleen. (*Telefunken Mitteilungen*, Sept. 1940, Vol. 21, No. 84, p. 17 onwards.)

A long illustrated summary of this 19-page survey is contained in *Rassegna della Stampa Tecnica Tedesca* [Rome], Jan./Feb. 1941, Electrotechnics pp. 66–69. *See* also 2708 of 1941 and 819 of 1944 : also 31 of January.

804. U.H.F. Converters and Conversion Diagrams.—H. Stockman. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 281 : summary of Nat. Electronics Conference paper.) *See* also 778, above.

805. Miniature Multi-Unit Valve Type 6AQ6 [Two Diodes & High-Mu Triode : only Half the Heater Current of 6Q7, and Lower Grid/Cathode & Plate/Cathode Capacitances]. — R.C.A. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, p. 209.)

806. The Magnetically Focused Radial-Beam Vacuum Tube.—A. M. Skellett. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, pp. 704–709.) A longer paper was dealt with in 3167 of 1944, where the final " t " of the author's name was omitted.

807. Limiting Stable Current in Electron Beams in the Presence of Ions.—J. R. Pierce. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, pp. 721–726.) A summary was dealt with in 3868 of 1944.

808. The Paths of Ions and Electrons in Non-Uniform Magnetic Fields [and the Promise of Such Non-Uniform Fields for Magnetic Analysers, etc.]. — Coggeshall & Muskat. (*See* 894.)

809. The Computation of Electron Trajectories in Axially Symmetric Fields, *and* Electron Ray Tracing through Magnetic Lenses.—Goddard, Klemperer. (*See* 892.)

810. Historical Background of Electron Optics.—C. J. Calbick. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, pp. 685–690.)

811. On Electron Multipliers with Magnetic Focusing [Improved Theory of the Trajectories].—Charles. (*See* 849.)

812. On the Influence of Adsorbed Oxygen on the Secondary Emission of Sublimated Metallic Films at 293° and 83° Absolute.—R. Suhrmann & W. Kundt. (*Zeitschr. f. Phys.*, 10th May 1943, Vol. 121, No. 1/2, pp. 118–132.)

This and a preceding paper were referred to in 1598 & 3877 of 1944. " If the clean surface of one of the nobler metals (Cu, Ag, Au) is acted on at room temperature by oxygen, the oxygen molecule is split up more or less into atoms which either diffuse into the interior of the metal or are adsorbed at its surface. In the latter case, owing to their high electron affinity they form a double layer with the negative charge directed outwards, and consequently thus increase the electronic work function. The result is a considerable reduction in the photoelectric electron emission of the metal.

" Since the secondary electrons possess on the average a greater initial velocity than the photoelectrons and are therefore less hindered by the emergence potential at the surface, the secondary emission is comparatively little affected by a change in the work function. Thus the oxygen atoms adsorbed at the surface alter the secondary-electron output very little. On the other hand, the oxygen dissolved in the uppermost metal layers may produce a temperature-dependence of the secondary emission. Whereas the s.e. of a clean metallic surface shows no appreciable influence of temperature between 83° and 293° absolute, the interaction between the metal lattice and the oxygen dissolved in the upper metallic layers may depend on the temperature, and therefore a temperature effect may make itself evident on the s.e. of a noble metal previously exposed to the action of oxygen.

" If a less inert metal (Be, Cd) is treated with oxygen, an oxide formation occurs at the surface. The oxygen taken up is thus more firmly bound than in the case of the nobler metal, so that an influencing of the interaction between metal lattice and oxygen by a change of temperature is less probable. For this reason the oxygen-treated surfaces of easily-oxidisable metals may be expected to show no, or only a small, influence of temperature on the s.e. output . . ."

It is these theoretical deductions that are confirmed by the experiments here described. Among other results, the great increase in room-temperature s.e. from the less noble metals, produced by the action of oxygen, is brought out : and it is suggested that this effect may be the explanation of Gorlich's increased s.e. from Be and Ca after an hour's glow discharge in a rare gas (3054 of 1941) : for although the oxygen impurity was only between 0.01 and 0.001%, it would be enough, under the glow discharge, to supply the surface with oxygen.

813. Potential Nuclear Monokinetic Electron Sources [Table of 68 Artificial Radioactive Nuclei emitting Electrons in a Narrow Energy Range, with Comments & References].—M. L. Pool. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, pp. 716–717.)

A summary was dealt with in 3870 of 1944. " There are a few nuclear sources which even now can be made to furnish currents of the order of 10^{-8} ampere " : with the availability of larger cyclotrons, " more intense monokinetic sources could be produced and the scope of appliability would be correspondingly enlarged ".

814. On the Growth and Structure Forms of Tungsten Crystals, and in Particular on the " Direct-Current Effect " [due to Ions migrating under the Influence of the Electric Field (*cf.* Benjamin & Jenkins, 101 of 1941)].—R. W. Schmidt. (*Zeitschr. f. Phys.*, 16th Nov. 1942, Vol. 120, No. 1/2, pp. 69–85.)

815. Filament and Heater Characteristics [Analysis of Volt/Ampere Characteristics of

Various Filament Metals: Resulting Equations plotted as Reference Chart "giving Filament Current, Temperature, & Wattage for Any Electron Tube at Various Operating Voltages with Good Accuracy": including the Case of Valves in Series].—C. E. Haller. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 126–130 and 354..356.)

816. The Noise of Thermionic Valves and Its Influence on the Noise of a Circuit.—W. Engbert. (*Telefunken Mitteilungen*, Sept. 1940, Vol. 21, No. 84, p. 49 onwards.)

A long illustrated summary of this 6-page paper is given in *Rassegna della Stampa Tecnica Tedesca* [Rome], Jan./Feb. 1941, Vol. 19, Electrotechnics pp. 71–73. *Cf.* also 1102 of 1943.

817. The Importance of Measurement in the Recent Improvement of Thermionic Valves [and a Survey of the Methods employed].—W. Graffunder. (*Telefunken Mitteilungen*, Sept. 1940, Vol. 21, No. 84, p. 55 onwards.)

A long Italian summary of this 14-page paper is contained in *Rassegna della Stampa Tecnica Tedesca* [Rome], Jan./Feb. 1941, Vol. 19, Electrotechnics pp. 51–53. The noise-measuring circuit of Fig. 1 employs two alternative noise-sources for comparison with the unknown noise. In the first method the grid circuit of the valve I under test is short-circuited (by the commutator *S*) and, with the saturated diode II extinguished, a deflection α is read on the meter: the grid circuit is then introduced and its variable resistance $R_{\ddot{a}}$ adjusted until the deflection becomes 2α: then the value of $R_{\ddot{a}}$ is the equivalent noise-resistance. In the second method the grid circuit of the valve I is short-circuited and the heating of the diode II (and thus the diode current i_d) is varied till the deflection 2α is obtained. From these readings the "weakening factor" is obtained ($F = \sqrt{i_d/i_a}$).

The equivalent resistance and the weakening factor represent two measurements of noise which are not independent, being linked by a relation involving the slope of the valve. Fig. 2 shows an a.c. bridge circuit for the rapid and accurate measurement of slope. Methods of measuring the distortion factor are described (in the full paper) including a compensation method with automatic regulation up to the equilibrium condition. But the coefficient of distortion does not give a very informative idea of the distortion, and the writer therefore describes a method of analysing the valve characteristic, based on the determination of the first, second, and third derivatives, and revealing its structure, point by point, with great accuracy: *see* Fig. 3, giving the $\partial^3 i_a/\partial U_g^3$ curves of a screen-grid valve, for three different control-grid alternating voltages. Short-time tests by pulse-excitation are discussed (Fig. 4). The special measuring methods for ultra-high frequencies "are given only a few notes, the specialised literature being referred to for details."

818. Review of Demountable *versus* Sealed-Off Power Tubes.—I. E. Mouromtseff, H. J. Dailey, & L. C. Werner. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 653–664.)

Conclusions: "It seems that a careful comparison of the virtues and drawbacks of demountable and sealed-off tubes with equal power per tube would surely lead to a verdict in favour of the sealed-off type . . . However, if one demountable tube can replace several sealed-off tubes, the situation may be quite different, as not only the number of tubes in operation will be reduced but the entire equipment may be simplified. In each industrial project the solution may vary.

"As to the necessity of having vacuum pumps in operation and the attending personnel, one may be reminded that recent years of defence work showed that even unskilled personnel may be trained sometimes to perform complicated operations. It seems that demountable tubes have much less chance in radio transmitters when even short interruptions are intolerable. This can be illustrated by the suggestion of Metropolitan-Vickers designers of the demountable tubes to have sealed-off tubes as spares in radio transmitters. Yet, even in radio, demountable tubes can find application in special cases when tubes of a new design are required in numbers not large enough to justify the development and manufacturing expense of the sealed-off type."

819. Correspondence on "The Validity of the Equivalent-Plate-Circuit 'Theorem' for Power Calculations" [3169 of 1944].—A. Preisman; H. Stockman. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, pp. 642–643.)

820. Power Efficiency in Non-Linear Transmission Systems [with Valves operating as Class B or Class C Amplifiers: the Great Value of the Chaffee Contour-Diagram Method of Analysis: Necessity for Standard Definitions of Various Power Efficiencies & Their Theoretical Limits: etc.].—H. Stockman. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 134–137.) *Cf.* 778, above.

821. Circuit Symbols Standardised [Compromise reached at March Meeting].—American Standards Association. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 92–93.) *See* also 970, below.

DIRECTIONAL WIRELESS

822. "Theory of the Coastal Refraction of Electromagnetic Waves": Errata.—G. A. Grünberg. (*Journ. of Phys.* [of USSR], No. 2, Vol. 7, 1943, Inset at Beginning.) *See* 3386 of 1944.

823. Post-War Reorganisation: Aviation Radio Beacons [Letter prompted by Proposed Changes in Frequencies in America: the Need for Allocation on a Global Basis, so that Each Beacon Frequency may identify Latitude or a Longitudinal Great Circle].—A. H. Morse. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 379.)

824. Antenna Design for Field-Strength Gain [Theory of the Considerable Gain found Experimentally at Pittsburgh Radio Range (200 & 400 kc/s) by Use of Four Identical Towers (Less than $\lambda/4$) at Corners of Square, instead of Single Similar Tower fed with Same Total R.F. Power].—H. W. Kohler. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, pp. 611–616.)

On 400 kc/s the calculated gain of r.m.s. field

strength in the horizontal plane was 1.48, the measured gain 1.61 : on 200 kc/s the values were 1.82 and 2.07 (12% discrepancy between calculated and measured results, instead of the 8% on the higher frequency). The gain obtainable is the higher, the larger the loss resistance (coil and ground resistance) and the smaller the spacing, so long as the coupled reactance remains small compared with the self-inductance of a single aerial. No gain is obtained when the loss resistance is zero : thus there is no gain with ultra-high frequencies, because then the radiators are $\lambda/2$ or $\lambda/4$ long, requiring no loss resistance for tuning and grounding.

825. MARINE NAVIGATION AIDS : THE RADIO DIRECTION FINDER AND THE GYRO-COMPASS [and Their Automatic Coordination : Fundamental Principles of the Gyro-Compass, etc.]. —E. H. Price & W. J. Gillule. (*Elec. Communication*, No. 1, Vol. 22, 1944, pp. 56–69.) From the Mackay Radio & Telegraph Company.

826. "MARINE AND AIR NAVIGATION" [Book Review].—J. Q. Stewart & N. L. Pierce. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 267.) "Timely and up to date. Everything is here . . ."

827. "SPHEROGRAPHICAL NAVIGATION" [Book Review].—D. Brouwer, F. W. Keator, & D. A. McMillen. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 266.) "A masterpiece of careful exposition and economy of words."

828. MAGNETIC DIRECTION INDICATOR [with Fixed Vertical Dial].—Autoflight Corporation. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 275.)

ACOUSTICS AND AUDIO-FREQUENCIES

829. A THEOREM ON THE ENERGY STORED IN A REACTIVE TWO-POLE. — Kessenich. (*See* 759.)

830. FEEDBACK AND THE LOUDSPEAKER : A LITTLE IS GOOD : MORE MAY NOT NECESSARILY BE BETTER [Negative Feedback may result in Loss of "Top" : Pitfalls & Their Avoidance]. —S. W. Amos. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, pp. 354–357.) For a correction *see* issue for Jan. 1945, p. 22.

831. RADIO-FREQUENCY VOLUME EXPANSION [Suggested Alternative to Recent Volume-Expansion Methods all altering Gain of A.F. Amplifier].—C. R. Cosens. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 381.)

832. THE MECHANISM OF SUPERSONIC FREQUENCIES AS APPLIED TO MAGNETIC RECORDING [in the "High-Frequency Bias" System].—H. Toomim & D. Wildfeuer. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 664–668.)

In the ordinary magnetic recorder, as developed by Stille, the magnetising head saturates the medium before the signal acts on it. In the "h.f. bias" system (Pugsley, 2611 of 1944) the recording takes place on a magnetically neutral medium. Ordinarily, large amounts of odd-harmonic distortion would occur, the input/output characteristic being of the type seen in Fig. 1, highly irritating to the ear and rendering speech almost unintelligible. A suitable amount of "h.f. bias" (produced by introducing, with the signal, a supersonic component which traverses several cycles during the time an elementary length of the medium is in the magnetic field) causes the recording characteristic to be linear to the origin and symmetrical in the first and third quadrants about the origin, as in Fig. 2. A transfer characteristic of this shape "overloads in a manner which is only slightly irritating and maintains the essential intelligibility of speech, even though greatly over-loaded."

In explanation of this improved recording, various writers have adduced an "action of the h.f. field in overcoming a sort of static friction in changing the magnetic orientation of the fundamental magnetic aggregates," although at the same time they recognised the inadequacy of the explanation. "It must be realised, of course, that this hypothesis does not explain the failure of the friction to reappear once a cyclic condition has been established in the medium, even at the point where the magnetic induction may be zero."

The present writer shows, by an oscillographic investigation using a modified form of Adler's B/H curve tracer (1662 of 1944), that the linearity at the origin, given by the "h.f. bias" method, is the consequence of the resulting shape of the cyclical hysteresis loop. The apparatus described makes possible the simultaneous viewing of the major and minor hysteresis loops; "it becomes possible to determine characteristics of magnetic materials which have not been heretofore well known and understood . . ." An added note mentions Camras's patent No. 2 351 004, the text of which is found to be broadly parallel to certain of the subject matter of the present paper : *cf.* also 1228 of 1944.

833. INVESTIGATIONS OF MAGNETIC-TAPE RECORDERS [Measurements, by the "Parameter-Elimination" Procedure, of Output Level & Harmonic Distortion as Functions of Frequency, Input Level, Pole Displacement, and Polarising & Obliterating Voltages].—M. C. Selby. (*Electronics*, May 1944, Vol. 17, No. 5, pp. 133–135 and 302.) From the Nat. Bureau of Standards.

834. SPEECH-TRAINING MACHINE [for R.C.A.F. Radiotelephone Operators : Use of the "Mirrophone" (2747 of 1943)]. — Bell Telephone Laboratories. (*Electronics*, June 1944, Vol. 17, No. 6, p. 105.)

835. SYNTHETIC MUSIC [Continuation of Correspondence dealt with in 495 of February].—P. Stevenson ; Hartley. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 380.) The writer of the original article defends himself.

836. HIGH-QUALITY RECORDINGS [American and English : Continuation of Correspondence dealt with in 494 of February].—D. W. Aldous : Hartley. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, pp. 380–381.)

837. RELATION BETWEEN DISSONANCE AND CONTEXT [a New Experiment, in an Attempt to meet Some of the Criticisms of Previous Work (493 & 1237 of 1944].—P. A. D. Gardner & R. W. Pickford. (*Nature*,

26th Aug. 1944, Vol. 154, No. 3904, pp. 274–275.)

The experiment provided evidence that the musical standards, opinions, or preferences of the subjects were factors in determining dissonance level, but of far less less importance than the effects of varying the musical context.

838. On the Tones of Thin Cylindrical Tubes. —G. E. Allan. (*Phil. Mag.*, Sept. 1944, Vol. 35, No. 248, pp. 571–582.)

839. Letter on "Acoustics of Small Rooms" [501 of February: the Problem of Too Short a Reverberation Period: the Poste Parisien Experiments on Artificial "Echo": a "Reverberation" Knob on High-Fidelity Receivers ?].—R. G. Young: Moir. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, pp. 379–380.)

840. Absorption of Sound by Porous Material. —C. Zwikker & others. (*Physica*, April 1943, Vol. 10, p. 239 onwards.) A 9-page paper, referred to in *Review Scient. Instr.*, Sept. 1944.

841. Dependence of Sound Absorption in Dielectrics on Frequency and Temperature.—I. Pomeranchuk. (*Journ. of Phys.* [of USSR], No. 6, Vol. 7, 1943, p. 266 onwards.) A 6-page paper mentioned in *Review Scient. Instr.*, Oct. 1944.

842. Fundamentals of Hearing-Aid Design [especially the Need for Selective Amplification, including a New Way of controlling the Frequency Response, particularly suitable for Receivers with Capacitive Internal Impedance].—W. D. Penn. (*Elec. Engineering*, Oct. 1944, Vol. 63, No. 10, Transactions pp. 744–749.)

843. Letter on "Phase-Shift Oscillators" [2161 of 1941].—A. Blanchard: E. L. Ginzton & L. M. Hollingsworth. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, p. 641.)

"Very interesting and useful, and the one-tube *R-C* oscillators are quite stable and satisfactory." A correction is suggested "to complete the usefulness of the discovery".

844. Portable Audio-Frequency Standard [generating 1582 c/s: primarily for Adjustment of Carrier-Current System's Signal-Oscillator Circuits: with Tuning-Fork Control].—W. Fayer. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 100–101.) A drift of $\frac{1}{2}$ c/s can be detected aurally, or 1 cycle in 30 seconds visually.

845. Theory of Ultrasonic Interference [Criticism of Classical Theory: Theory taking Account of Non-Uniformity of Acoustic Field: Resulting Improvement of Methods of measuring Velocity & Damping Coefficient: etc.].—P. E. Krasnooshkin. (*Journ. of Phys.* [of USSR], No. 2, Vol. 7, 1943, pp. 80–91: in English.) *See* also 2914 of 1944. For corrections, *see* inset at beginning of No. 3, Vol. 7.

PHOTOTELEGRAPHY AND TELEVISION

846. Technical Plan for Post-War Television ["a Vast New Empire, including 26 Commercial Channels from 50 to 246 Mc/s, with Relaying & Experimental Channels extending above 10 000 Mc/s"].—Panel of R.T.P.B. (*Electronics*, Aug. 1944, Vol. 17, No. 8, pp. 92–97 and 164, 168, 172.)

847. Improved High-Frequency Compensation for Wide-Band Amplifiers [for Television, Cathode-Ray Oscillographs, etc: Analysis by Ordinary Circuit Theory, Simpler than Wheeler's Filter-Circuit Treatment (3641 of 1939): Explanation of the "Unexplained" Over-Compensation often given by Ordinary Compensation Calculations: Proper Design of Single (Inductance) Compensating Element gives Results equivalent to Those of a Two-Element Arrangement].—A. B. Bereskin. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, pp. 608–611.)

The single-element circuit given provides, at no additional cost, uniform response to a frequency about half an octave higher than that obtained with the most extensively used single-element arrangement. "It appears reasonable that the method indicated here should be adopted in the future in all applications in which the ordinary type of compensation was previously used."

848. Ultra-Violet-Sensitive, High-Vacuum, 9-Stage Multiplier Phototube with Electrostatic Focusing, Type 1P28.—R.C.A. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, p. 209.)

849. On Electron Multipliers with Magnetic Focusing.—D. Charles. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 556–558.)

Up to the present the motion of the electrons has been calculated by assuming the electric field to be uniform: "this summary representation gives a very inexact image of the end of the trajectories and of the bombardment of the plates by the electron beam. It is this that has led us to perfect the theory."

The corrections arrived at, for application to the elementary theory, are as follows:—"The real electric field produces a slight effect of concentration on the trajectories issuing from different points of the same emitting plate: for the electrons issuing from the same point, and for a given orientation of the initial velocity, the trajectories are practically independent of the value of this velocity. On the other hand, they differ completely when its orientation changes.

"For electrons issuing from different points of the emitting plate, the angle of incidence varies; it varies also with the orientation of the initial velocity, for trajectories issuing from the same point. In no case is the incidence normal. The incidence varies with the applied potential, provided that for each value of potential H is adjusted so as to keep the quotient $H/\sqrt{V}$ constant."

850. Fatigue in Selenium Rectifier Photocells [Effect described by Preston (2920 of 1944) may be connected with Increased Departure from Linearity of Response to Wavelengths

above about 0.66μ (Atkins & Poole)].—H. H. Poole: J. S. Preston. (*Nature*, 26th Aug. 1944, Vol. 154, No. 3904, p. 274.)

In his reply, on the same page, Preston remarks that the two sets of results point to a close correlation between various properties of the cells, as Poole suggests: "and there now seems good reason to believe that the basic common factor is the existence of a photoelectric, and an associated transparency, threshold in the neighbourhood of 0.66μ or 0.64μ. The way in which this factor enters into the action of the cell is certainly of practical interest and may be of fundamental importance . . ."

MEASUREMENTS AND STANDARDS

851. A Method for the Generation of Quasi-Continuous Frequency Spectra for Use with Secondary Frequency Standards [with Special Reference to the Micro-Wave Region: the Silicon Crystal as an Excellent Non-Linear Element for Generation of Harmonics: a Secondary Frequency Standard up to at least 10 000 Mc/s].—H. Goldberg & R. G. Talpey. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 281–282: summary of Nat. Electronics Conference paper.)

The standard described has a multiplier chain based on a stabilised quartz-crystal oscillator of frequency f: the frequencies occurring in the chain are summed and applied to a final silicon-crystal harmonic generator. The result is a spectrum starting with f and supplying frequencies nf for orders of n which may exceed 1000. Identification is carried out with a coaxial-line type of wavemeter, and detection by means of a superheterodyne detector with no pre-selection and with a silicon-crystal mixer followed by a wide-band i.f. amplifier and an a.f. amplifier.

852. On Foucault Currents in an Ellipsoid of Revolution [Preliminary to the Work dealt with in 2639 of 1944].—M. Jouguet. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 523–524.)

853. Measurement of Reactances in the Decimetric-Wave Region.—L. Brück. (*Zeitschr. f. Fernmeldetech.*, 10th Sept. 1943, Vol. 24, No. 6, p. 87: summary, from *Telefunken-Röhre*, Oct. 1942, No. 24/25.) A 10-page paper giving the principles and practical points of the resonant-circuit method using a transmission-line section with adjustable short-circuiting plate.

854. Vacuum-Tube Voltmeter [Models 200 & 201: "covering the Entire R.F. Range of 200 Mc/s but linearly responsive to the Low A.F. Range of 20 c/s": utilising "Several Little-Known Principles of the Vacuum Tube"].—Televiso Products. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 272–273.)

855. Sensitivity Calibration of Receivers: a Radiation Method for Wavelengths below 10 Metres.—McPetrie, Perry, & Ford. (*See* 776.)

856. Measurement of Background Noise by Thermocouple and by a Rectifier-Type Meter.—J. Baurand & B. Vallantin. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 555–556.)

A summary was referred to in 2270 of 1944. Calculation, confirmed by experiment, having shown that the square-law thermocouple and the linear full-wave (bridge-type) rectifier instrument gave different readings for the superposition of two sinusoidal currents (50 c/s and 1 kc/s), the question arose whether the same thing would happen for background-noise currents, considered as the resultant of an infinite number of currents of different frequencies and phases, distributed at random.

Tests on the background noise of two quite different amplifiers, with the two measuring instruments in series with each other, showed that for the first amplifier (selective, tuned to 1000 c/s, with a pass band of 60 c/s) the two instruments agreed within less than 6%. For the second amplifier (non-selective, but with output noise filtered to retain only the 0–3000 c/s frequencies) the difference was less than 10%. This larger difference may have been due to the filter passing some of the higher frequencies, since the calibration of the rectifier meter varies with frequency above 1500 c/s. The writer concludes that, under the conditions described, either type of instrument may be used.

857. Natural Limits of Measuring Radiation with a Bolometer.—J. M. W. Milatz & H. A. van der Velden. (*Physica*, June 1943, Vol. 10, p. 369 onwards.) A 12-page paper, referred to in *Review Scient. Instr.*, Sept. 1944.

858. Reduction of Spontaneous Fluctuations in Vacuum-Tube Electrometer Circuits through Mechanical Conversion.—H. den Hartog & F. A. Muller. (*Physica*, March 1943, Vol. 10, No. 3, p. 167 onwards.)

A 6-page paper on the design of frequency converters for the reduction of the grid noise in electrometer valves. It is possible to construct a fully mains-driven equipment with a sensitivity of ten electrons per second.

859. On the Deflection of Anisotropic Thin Plates.—V. Morkovin. (*Quart. Applied Math.* [Brown University], July 1943, Vol. 1, No. 2, pp. 116–129.)

860. Longitudinal Vibrations of Rectangular Quartz Plates.—R. Bechmann. (*Zeitschr. f. Phys.*, 16th Nov. 1942, Vol. 120, No. 1/2, pp. 107–120.)

Continuation of the work dealt with in 2183 of 1941 and 1757 of 1942. In the first paper the solution of the longitudinal vibrations of infinitely thin rectangular plates of an anisotropic material was found as the limiting case for one decreasing dimension. In the second paper the range of validity of this solution was investigated for square quartz plates of various cuts: for longitudinal vibrations good agreement was found between the derived equation of frequency and the measured results: for the shear vibrations an empirical correcting term independent of the orientation of the plate was found necessary.

The present paper examines the validity of the solution in the case of narrow thin rectangular

quartz bars. Using the correction already mentioned for the natural frequency of the shear vibration, "a very satisfactory agreement is found between calculation and measurement for the two longitudinal degrees of freedom. The characteristic of the natural frequencies of the shear vibration as a function of plate shape is completely changed, from that calculated, by the influence of a flexural vibration: a phenomenon that occurs also with a plate cut perpendicular to the optical axis, which behaves like an isotropic plate.

"Some special effects occurring with quartz crystals are also pointed out. In quartz, the coefficient of transverse contraction may assume both positive and negative values, including zero, in which case a coupling of the two longitudinal degrees of freedom disappears. For a special direction the propagation velocity of elastic waves is practically independent of the dimensions of the body, so that the difference between the propagation velocity of a plane wave in an infinitely extended medium and that in an infinitely thin bar almost disappears": Fig. 7 and adjacent text.

861. Remark on Kirschstein's Paper "A Method for the Exact Regulation of Fixed Rotational Speeds of an Axle" [1484 of 1943].—K. Boedeker: F. Kirschstein. (*Zeitschr. f. tech. Phys.*, Jan. 1943, Vol. 24, No. 1, p. 17.)

Boedeker & Riegger's similar arrangement, patented in 1917, has been successfully used for the frequency-control of large radiotelegraphic transmitters. On p. 18, Kirschstein points out the difference between the two methods.

862. On the Temperature Coefficient of Air-Cored Self-Inductances.—A. Bloch. (*Phil. Mag.*, Oct. 1944, Vol. 35, No. 249, pp. 693–705.)

"It is well known that the inductance of a coil changes with temperature much more than one would expect from the thermal changes of the coil dimensions. The discrepancy may be of the order of several hundred per cent. The reason for this is that the change in temperature causes, amongst other things, a change in the resistivity of the coil wire (and of other conductors situated in the magnetic field of the coil) and influences thereby the extent to which the magnetic field penetrates into these conductors. In a previous paper (3112 of 1944) the author has shown how to calculate this effect in a simple manner for the practically very important case in which the current flow is restricted to a thin skin at the surface of the conductor. The purpose of the present paper is to give a solution for the case where this assumption is no longer justified."

Butterworth, to calculate the power losses in the coil wire, evaluated the real part of the complex form of Poynting's Integral taken over the surface of the wire. Douma (2716 & 3712 of 1938) evaluated the imaginary part (giving the wattless power associated with the field inside the conductor) and assumed that he had thus determined the "internal" reactance of the coil. But the penetration of the magnetic field into the conductor alters also the field surrounding the conductor, and it is the *total* change in the stored magnetic energy which is responsible for the "internal" reactance (*i.e.* for the additional reactance caused by the fact that the resistance of the wire is not zero). Thus Douma's results have to be, in part, revised.

The paper discusses also the variation of the coil inductance with change in the geometrical dimensions, including the case where the wire-material has a coefficient of thermal expansion differing from that of the coil former. Finally, an example is worked out in accordance with the writer's developments, for a 105 μH inductance of 82 turns on a ceramic former. The total temperature coefficient works out at 14×10^{-6} parts per degree C: to this may be added, presumably, 1 or 2×10^{-6} parts on account of the temperature change of the self-capacitance of the coil. The measured value was 15.9×10^{-6} parts per degree C.

863. The Calculation of the Mutual Inductance of Circular Filaments in Any Desired Positions.—Grover. (*See* 770.)

864. The Importance of Measurement in the Recent Improvement of Thermionic Valves.—Graffunder. (*See* 817.)

865. Amplifier Testing with Square and Triangular Waves [Short Bibliography of Papers between 1937 & 1944, headed by the Writer's Original Paper (1931 Abstracts, p. 330)].—H. J. Reich. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, p. 715.)

866. Saving Mica by Testing [Tests devised so that No Good Mica of Any Type should be Rejected: Test Sets for detecting Conducting Regions & for measuring Dielectric Loss of Raw Mica in Block Form].—K. G. Coutlee. (*Bell Lab. Record*, Sept. 1944, Vol. 22, No. 13, pp. 509–513.)

867. Voltage-Breakdown Tester and Test Fixture, Type P-3.—Industrial Instruments. (*Review Scient. Instr.*, Sept. 1944, Vol. 15, No. 9, p. 231.)

868. A Suggestion for Reducing the Consumption of Anode and Flash-Lamp Batteries [especially for Military Testing Equipment: in Many Cases a D.C. or A.C. Supply is Available: Proposed Provision of a Special Universal Mains Adaptor].—G. Gies. (*Zeitschr. f. Fernmeldetech.*, 15th Jan. 1943, Vol. 24, No. 1, pp. 10–12.)

869. Moving-Coil Rectifier-Type Instruments for A.C. Measurements [and the Errors due to Temperature, Frequency, Aging, & Wave-Form].—K. Maier. (*Arch. f. Tech. Messen*, May & June 1940, Parts 107 & 108: long summary, in Italian, in *Rassegna della Stampa Tecnica Tedesca* [Rome], May/June 1940, Electrotechnics pp. 157–162.)

870. A Unique Moving-Magnet Ratio Instrument.—F. R. Sias & N. B. Fisk. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, Transactions pp. 634–636.) A summary was dealt with in 3548 of 1944.

871. Alternating-Current Coulometer.—J. A. M. van Liempt & others. (*Physica*, Jan./Feb. 1943, Vol. 10, No. 1/2, p. 1 onwards.) Referred to in *Review Scient. Instr.*, Aug. 1944.

872. "Galvanómetros y Oscilógrafos" [Vol. I—Galvanometers: Book Review].—S. Gerszonowicz. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 264.)

"The final, and in many ways the most interesting, chapter is entitled 'A critical study of the catalogues: numerical data on galvanometers of current construction' . . ." The whole review is very favourable.

873. Influence of Friction on the Functioning of Indicating Apparatus [and the Need for Consideration, in the Design of the Linking Mechanism, of an Effect (additional to That of False Equilibrium) of Motion in Jerks].—F. Charron. (*Comptes Rendus* [Paris], 4th/26th Oct. 1943, Vol. 217, No. 14/17, pp. 315–317.)

874. A Circuit for measuring Temperatures by a Resistance Thermometer [Special Double-Diode Circuit with Various Advantages, including Independence of Fluctuations of Mains Voltage & Room Temperature].—R. Guillien. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 521–522.)

875. Reform of Electrical Units [Letter on Durack's Plea for Simplification (136 of January): Is It True that "Practical Units are Too Cumbersome for Use in Theory"? Universal Adoption of Practical Units, as proposed by Giorgi and Campbell, would benefit Students & Physicists as well as Engineers].—P. Vigoureux. (*Wireless Engineer*, Jan. 1945, Vol. 22, No. 256, pp. 13–14.)

876. The Conversion Factors from International to Absolute Electric Units.—U. Stille. (*Zeitschr. f. Phys.*, 10th May 1943, Vol. 121, No. 1/2, pp. 34–53.) With values for p, q, pq, and pq^2. For the writer's book *see* 2937 of 1944. The paper leads up to a long work on "The Atomic Constants e, e/m_0, and h" in the issue for 20th June 1943, Vol. 121, No. 3/4, pp. 133–200.

877. Standardised Components: I—Properties of Resistors [and the Future Influence of Wartime Measures on the Industry's Post-War Work].—T. Roddam. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, pp. 370–373.) Following on 532 of February.

SUBSIDIARY APPARATUS AND MATERIALS

878. New Results of High-Performance Oscillography [and the Attainment of Recording Speeds equal to One-Third of the Velocity of Light].—Egerer, Ganswindt, & Pieplow. (*Zeitschr. f. tech. Phys.*, Jan. 1943, Vol. 24, No. 1, pp. 3–8.)

"The high-performance cathode-ray tube developed from 1938 onwards (Katz, Westendorf: 501 of 1942 and back references, 1946 of 1943), with electrostatic ray-concentration and electric deflection, formed the basis for the building-up of a new branch of oscillographic measuring technique (Pieplow, 502 of 1942). The introduction and trial of the high-performance oscillograph (Ganswindt, 503 of 1942) in cable testing and high-voltage engineering (Rabus, ref. "4") showed conclusively the superiority of the sealed-off tube, not only as regards its convenience but also in its absolute performance; and further, it brought about the inclusion of the completely new field of decimetric-wave oscillography (Ganswindt & Pieplow, 197 of 1942 and back reference)."

Recent development has seen no important changes in the circuits (time-base, etc.) of the equipment, since these were initially designed to fulfil all likely requirements. Changes in the tube itself have consisted chiefly in improvements in the formation of the cathode and the fluorescent screen, not described here. The paper deals particularly with the latest photographic-recording technique, using a Leica camera with special lenses (1 : 1 or 1 : 2) and Agfa-Fluorapid film: the generation of satisfactory test voltages (with a deflecting system of 5 pF capacitance, the load is such that in a testing laboratory the only plan is to use a small u.s.w. transmitting triode with pulse excitation of the anode): and a discussion of the "absolute resolving power" (optical resolving power divided by maximum recording speed). Fig. 11 shows an oscillogram (natural size) of a 55 cm wave, taken at a recording speed of 110 000 km/s. From this and the oscillogram of Fig. 10 it is seen that, using Malsch's suggested criteria of performance (maximum speed divided by spot diameter, sensitivity divided by spot diameter) the performance is definitely better than that of any oscillograph previously reported on: and the anode voltage is only 20 kv.

879. Portable Cathode-Ray Oscillograph, Type 248.—Du Mont Laboratories. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, pp. 210–211.) With "many interesting features." For the Type 247 *see* 139 of January.

880. Phototechnical Experiments with a Single-Beam Cathode-Ray Oscillograph [for the Recording of Several Simultaneous Phenomena: Limitations of the Multivibrator Switching Method: Outline of Method of Photographing, in Succession & on the Same Plate, the Separate Traces of the Various Phenomena: Specimen Results].—Fritzsch. (*Zeitschr. f. Fernmeldetech.*, 15th Jan. 1943, Vol. 24, No. 1, pp. 12–13.)

881. Constant-Voltage Phase Adjuster, with Single-Knob Adjustment [for Thyratron Control, C.R. Time Bases, etc.].—Dehors. (*See* 766.)

882. A Stable Direct-Coupled Amplifier [for Cathode-Ray-Tube Deflection, etc.].—Mezger. (*See* 746.)

883. Improved High-Frequency Compensation for Wide-Band Amplifiers.—Bereskin. (*See* 847.)

884. The Electrostatic Emission-Type Electron Microscope [Two-Stage, with a Johannson Immersion Objective modified for the Requirements of High Field Strengths: Resolving Power 40 mμ or Better, with 20 kv Accelerating Voltage: Application to Investigation of Ba–Sr Paste Cathodes].—Mecklenburg. (*Zeitschr. f. Phys.*, 16th Nov. 1942, Vol. 120, No. 1/2, pp. 21–30.)

885. THE ELECTRON MICROSCOPE IN METALLURGICAL RESEARCH, *and* EXTENDING MICROSCOPIC EXAMINATION OF METALS.—Barrett: Keller & Geisler. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, pp. 691–696: pp. 696–704.)

886. SURFACE ELECTRON MICROSCOPY OF GLASS AND CERAMICS BY THE REPLICA PROCESS [hitherto chiefly confined to Metallic Surfaces].—Gölz. (*Zeitschr. f. tech. Phys.*, Jan. 1943, Vol. 24, No. 1, pp. 8–11 and Plates.)

887. THE THICKNESS OF ELECTRON-MICROSCOPIC OBJECTS [and Its Determination: the Importance of Electron-Diffraction Effects in the Object in vitiating Results given by Stereoscopic Photography: Development of Shadow-Casting Method, giving Estimates in the Range of Molecular Dimensions].—Williams & Wyckoff. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, pp. 712–716.)

888. STEREOSCOPY WITH THE ELECTRON MICROSCOPE [Description of a Universal Stage allowing Tilting of Object to Any Desired Angle by External Control: Specimen of Results at Large Viewing Angles].—Marton. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, pp. 726–727.)

889. DIRECT CENTRIFUGATION ON TO ELECTRON MICROSCOPE SPECIMEN FILMS [Description of Simple Apparatus & Technique].—Crane. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 253.)

890. THE SUITABILITY OF PHOTOGRAPHIC LAYERS POOR IN BINDING MATERIAL [such as the Agfa–Schumann–Hart I Plate] IN ELECTRON MICROSCOPY.—von Ardenne. (*Zeitschr. f. Phys.*, 10th May 1943, Vol. 121, No. 1/2, pp. 1–6.)

The writer mentions his work (now in progress) with ray-voltages of 200 kv and greatly increased thickness of layer.

891. ELECTRON-OPTICAL IMAGE FORMATION IN THE CASE OF IMPERFECT SYMMETRY OF ROTATION [and the Consequent "Axial Astigmatism": Calculation of the "Circle of Least Blurring": etc.].—Glaser. (*Zeitschr. f. Phys.*, 16th Nov. 1942, Vol. 120, No. 1/2, pp. 1–15.)

In connection with the search for the explanation of the fact that the transmission-type electron microscope has, in practice, a resolving power worse by a factor of 4 than that predicted by the full theory. Such imperfect symmetry might arise either in the mechanical construction or through magnetic inhomogeneity of the pole-piece material.

892. THE COMPUTATION OF ELECTRON TRAJECTORIES IN AXIALLY SYMMETRIC FIELDS [Limitations of Existing Methods: New Method with Several Advantages, applicable in a Combined Electric & Magnetic Field, and Not Limited to Paraxial Rays or Rays initially Parallel to Axis], *and* ELECTRON RAY TRACING THROUGH MAGNETIC LENSES.—Goddard: Goddard & Klemperer. (*Proc. Phys. Soc.*, 1st Nov. 1944, Vol. 56, Part 6, No. 318, pp. 372–378: pp. 378–396.)

(i) "We begin not with the paraxial equation, which *ipso facto* imposes a considerable restriction, but with the general equations of motion of the electron, and give formulae (taken for the most part from the calculus of finite differences) by which these may be solved numerically to give the path . . ." (ii) Defects of previous methods overcome by a new approach, based on Goddard's numerical method (i). "A simple and rapid method based on the paraxial equation is also given, for the sake of completeness. An experimental method of ray tracing, using a sliding fluorescent target, is then briefly described. The results obtained by the two computational methods and by the experimental method are compared, and the accuracy is discussed."

893. HISTORICAL BACKGROUND OF ELECTRON OPTICS.—Calbick. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, pp. 685–690.)

894. THE PATHS OF IONS AND ELECTRONS IN NON-UNIFORM MAGNETIC FIELDS [and the Determination of Dispersion & Focusing Characteristics of the Trajectories: the Promise of Such Non-Uniform Fields for Magnetic Analysers, etc.].—Coggeshall & Muskat. (*Phys. Review*, 1st/15th Oct. 1944, Vol. 66, No. 7/8, pp. 187–198.) A summary of a preliminary report was dealt with in 3866 of 1944.

895. LIMITING STABLE CURRENT IN ELECTRON BEAMS IN THE PRESENCE OF IONS.—Pierce. (*Journ. Applied Phys.*, Oct. 1944, Vol. 15, No. 10, pp. 721–726.) A summary was dealt with in 3868 of 1944.

896. POTENTIAL NUCLEAR MONOKINETIC ELECTRON SOURCES.—Pool. (*See* 813.)

897. REMARK ON HEIL'S "A NEW SOURCE OF IONS" [148 of January].—von Ardenne: Heil. (*Zeitschr. f. Phys.*, 12th Jan. 1943, Vol. 120, No. 3/4, p. 227.)

898. AN ATOM-TRANSFORMATION EQUIPMENT FOR VOLTAGES UP TO ONE MILLION VOLTS [with Alternative Beams of Deuterons, Protons, or Electrons, about 35 μA in Each Case].—von Ardenne, with Bernhard. (*Zeitschr. f. Phys.*, 20th June 1943, Vol. 121, No. 3/4, pp. 236–267.)

899. THE MAGNETICALLY FOCUSED RADIAL-BEAM VACUUM TUBE.—Skellett. (*See* 806.)

900. GRID CONTROL OF GAS-FILLED TUBES [Thyratrons & Ignitrons].—Cockrell. (*See* 765.)

901. MINIATURE FOUR-ELECTRODE THYRATRON, TYPE 2D21 [for Relay & Special Applications: handles 100 mA Average Output Current in Continuous Operation].—R.C.A. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, p. 209.)

902. MINIATURE DIFFUSION PUMP [Metal, for Vacua 1×10^{-6} mm of Hg: "Type VMF" Series, the Smallest only 6" High].—Distillation Products. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, p. 210.)

903. Spectroscopical Investigation of Ions in the Positive Column of a Glow Discharge [with Estimation of Drift Velocity, Velocity of Random Motion, etc.].—Frisch & Kagan. (*Journ. of Phys.* [of USSR], No. 5, Vol. 7, 1943, pp. 208–214: in English.)

904. On Plasma Transit-Time Oscillations.—Schumann. (*See* 773.)

905. Dielectric Losses of Various Glasses in the Short-Wave Region as a Function of Temperature.—Strutt & van der Ziel. (*Physica*, July 1943, Vol. 10, No. 7, p. 445 onwards.)

This six-page paper was referred to in 1685 of 1944. The relation $\tan\delta = A \cdot e^{aT}$, found in a previous investigation to hold at lower frequencies, is no longer accurate at 12–50 Mc/s. In agreement with previous results, the dielectric losses are less dependent on temperature, the higher the frequency; the same applies to the dielectric constant. Glasses containing much sodium have higher dielectric losses, and a larger variation of dielectric constant, than glasses of low sodium content.

906. Low-Loss Ceramics [Requirements: Test Methods (including the Errors with Foil Electrodes applied with Petrolatum Films, Effects of Moisture, etc.): Data on Zircon Porcelains, Steatite, Ultra-Steatite, Fused Quartz, etc.].—Russell & Berberich. (*Electronics*, May 1944, Vol. 17, No. 5, pp. 136–142 and 338.)

907. Heat Conductivity of Dielectrics at High Temperatures [and the Influence of Collisions between Four Phonons, due to Cubic Anharmonicity].—Pomeranchuk. (*Journ. of Phys.* [of USSR], No. 5, Vol. 7, 1943, pp. 197–201: in English.) For previous work *see* 569 of 1944.

908. Dependence of Sound Absorption in Dielectrics on Frequency and Temperature.—Pomeranchuk. (*See* 841.)

909. Electrostatic Properties of Rubber and GR-S [and a New "Electrostatic Modulator" for measuring Electrostatic Charges: Confirmation of the "Electrostatic Contact Potential Theory of Reinforcement"], *and* Speed of Retraction of Rubber [measured by Electronic Timing Circuit with Photocell Input].—Havenhill & others: Stambaugh & others. (*Journ. Applied Phys.*, Nov. 1944, Vol. 15, No. 11, pp. 731–740: pp. 740–748.)

910. Mechanisms for the Relaxation Theory of Viscosity [Disagreement with Eley & Pepper's Conclusions (3260 of 1944)].—Powell & Eyring. (*Nature*, 30th Sept. 1944, Vol. 154, No. 3909, pp. 427–428.) Eley & Pepper reply on p. 428.

911. "Quantum Chemistry" [Book Review].—Eyring, Walter, & Kimball. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 258.)

912. Saving Mica by Testing [so that No Good Mica of Any Type should be Rejected].—Coutlee. (*See* 866.)

913. Alternatives for Mica Capacitors [and particularly the Use of Low-Q Capacitors in Circuits where Mica has previously been Used Unnecessarily].—Hanson. (*Electronics*, May 1944, Vol. 17, No. 5, pp. 130–132 and 212.)

914. "Formex" Ribbon-Rectangular Magnet Wire [substantially Increasing the Winding-Space Factor, and with Other Advantages].—General Electric. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, p. 212.) For "Formex" magnet wires *see* 2232 of 1943 and back references.

915. H.F. Incremental Permeability Tuning [Measurements on Dust Cores].—Polydoroff. (*See* 785.)

916. Torsional Relay [Frequency-Selective Relay possessing Fine Stability over Wide Range of Ambient Temperature & Pressure, for Remote Control of Processes, etc: Series covering Band from 10 to 20 c/s].—Wallace & Tiernan Products. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, pp. 209–210.) "The new and unique principles . . . will suggest many new applications."

917. A Relay based on the Extremely High Temperature-Coefficient of Conductivity of Solid Electrolytic Conductors, especially near the Melting Point.—Volmer. (*Zeitschr. f. Fernmeldetech.*, 10th Sept. 1943, Vol. 24, No. 6, p. 86.) D.R.P.724 766/21c.

918. Influence of Friction on the Functioning of Indicating Apparatus.—Charron. (*See* 873.)

919. Effect of a Spherical Screen upon an Inductor.—Davidson & Simmonds. (*See* 769.)

920. The Behaviour of Stratified Resistances of High Value [*e.g.* Carbon Film on Ceramic Carrier] in High-Frequency Circuits.—Klemt. (*Arch. f. Tech. Messen*, Oct. 1940, Part 112, Sheets T117 onwards.) For a long summary, in Italian, see *Rassegna della Stampa Tecnica Tedesca* [Rome], Jan./Feb. 1941, Electrotechnics pp. 9–12: and for a later work *see* 1316 of 1942.

921. Standardised Components: I—Properties of Resistors.—Roddam. (*See* 877.)

922. Contribution to the Theory of the "Chopper" Transformer [of Car-Radio Vibrator].—Kiderlen. (*See* 789.)

923. A Suggestion for Reducing the Consumption of Anode and Flash-Lamp Batteries.—Gies. (*See* 868.)

924. Torque-Limiting Screw-Driver [on a New Spring Principle].—Richmont, Inc. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 274–275.)

925. Moistureproof Packaging [Use of Coating Compounds based on Vinylite Plastics].—

Carbide & Carbon Chemicals. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 276.)

926. FUNGUS-PROOFING PROCEDURE [for Electronic Equipment used in the Tropics].—Proskauer. (*Electronics*, June 1944, Vol. 17, No. 6, pp. 92–93 and 224..232.)

927. THE PACKING OF WAR STORES FOR TRANSIT TO THE TROPICS [Description of the Anglo-American Services Tropical Preservation & Packaging Exhibition, Feltham].—(*Engineering*, 17th Nov. 1944, Vol. 158, No. 4114, pp. 385–387.) *See* also *Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 364.

928. CLIMATE AND ITS ACTION ON MATERIALS IN THE TROPICS.—Schulze. (*Zeitschr. f. Fernmeldetech.*, 15th Jan., Feb., & March 1943, Vol. 24, Nos. 1, 2, & 3, pp. 1–10, 21–28, & 35–40.)

From the A.E.G. laboratories. For previous papers covering some of the same ground as this long work *see* 1672 of 1942 and 2230 of 1943. There is a bibliograohy of 119 items. Among the various factors dealt with, the action of sunlight on paints and varnishes is considered: the old idea that tropical sunlight is comparatively poor in ultra-violet has been exploded.

But really, apart perhaps from humidity and from ants, moulds, and other biological agents, the various "tropical" factors are equally possible to encounter somewhere or other in Germany itself—on high mountains, in aircraft, or elsewhere.

STATIONS, DESIGN AND OPERATION

929. U.H.F. REPEATER STATION [Unattended 312 Mc/s Relay to Flood-Control Headquarters during Noisy Daylight Hours when Medium Frequency Reception from Dam Stations is drowned by "City" Interferences].—Kennedy. (*Electronics*, June 1944, Vol. 17, No. 6, pp. 106–109.)

930. FREQUENCY MODULATION AND ITS POST-WAR FUTURE.—Brown. (*Electronics*, June 1944, Vol. 17, No. 6, pp. 94–99 and 262.) An analysis by the Asst. Vice President, Zenith Radio.

931. ARMY SETS: DETAILS OF SOME RADIO GEAR [Transceivers, Transmitter–Receivers, etc.].—(*Wireless World*, Dec. 1944, Vol. 50, No. 12, pp. 365–366.)

932. NEW ENEMY RADIO EQUIPMENT [Analysis of German & Japanese Sets manufactured in 1943: "Distinct Improvement over 1941/42 Models, with No Substitution of Critical Materials Whatsoever"].—Willig. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 132–133 and 356..362.)

933. AIRCRAFT RADIO MAINTENANCE.—Trumbull. (*See* 961.)

934. ELECTRONIC COMMUNICATION FOR TRAINS [Space Radio, Rail Carrier, & Induction Radio Systems, and Their Advantages & Disadvantages: etc.].—Halstead. (*Electronics*, Aug. 1944, Vol. 17, No. 8, pp. 102–107 and 262..274.)

935. CARRIER COMMUNICATION TO CRANE CABS [with all Transmission cleared through Central Desk: Advantages over Ordinary Telephone Systems].—Snedeker. (*Electronics*, Aug. 1944, Vol. 17, No. 8, pp. 112–114 and 377, 378.) With special receivers, made necessary by the very high electrical-noise level in the cabs.

936. SIGNIFICANT RADIATION FROM DIRECTIONAL ANTENNAS OF BROADCAST STATIONS FOR DETERMINING SKY-WAVE INTERFERENCE AT SHORT DISTANCES [and the Question of the F.C.C. "Standards"].—De Witt & Ring. (*See* 797.)

937. REORGANISING BROADCASTING [Suggestions for Post-War Broadcasting: Universal Frequency Separation of 10 kc/s: All Stations on Exact Multiple of 10 kc/s: Receivers calibrated in Multiples of 10 kc/s (ending the Frequency/Wavelength War): No Simultaneous or Common-Wave Broadcasting].—Boswell. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 379.)

MISCELLANEOUS

938. SUMS OF SERIES OF THE FORM

$$\sum_{0}^{\infty} a_n J_{n+\alpha}(z)\, J_{n+\beta}(z).$$

—Rice. (*See* 791.)

939. A NOTE ON A CERTAIN MULTIPLE INTEGRAL.—Gladwin. (*Phil. Mag.*, Oct. 1944, Vol. 35, No. 249, pp. 657–660.)

Defined by the equation

$$I_n(x, y) = \int_x^y f(u_1)\, du_1 \int_{u_1}^y f(u_2) du_2 \ldots \int_{u_{n-1}}^y f(u_n) du_n,$$

where $f(u)$ is a real single-valued function of a real variable u, and is continuous and finite in the closed interval $x \leqslant u \leqslant y$.

940. EIGEN-VALUES AND EIGEN-FUNCTIONS FOR THE OPERATOR $d^2/dx^2 - |x|$.—Bell. (*Phil. Mag.*, Sept. 1944, Vol. 35, No. 248, pp. 582–588.)

941. EXPANSIONS IN TERMS OF ASSOCIATED LEGENDRE FUNCTIONS.—MacRobert. (*Phil. Mag.*, Oct. 1944. Vol. 35, No. 249, pp. 670–680.)

942. THE NUMERICAL SOLUTION OF LAPLACE'S AND POISSON'S EQUATIONS.—Moskovitz. (*Quart. Applied Math.* [Brown University], July 1944, Vol. 2, No. 2, pp. 148–163.)

943. "THEORIE UND ANWENDUNG DER LAPLACE-TRANSFORMATION" [Book Notice].—Doetsch. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, p. 354.) A reproduction of this "classic monograph", with a German–English glossary added.

944. "DIE DIFFERENTIAL- UND INTEGRALGLEICHUNGEN DER MECHANIK UND PHYSIK": [Vol. 1—Mathematics: Vol. 2—Physics: Reproduction of Second German Edition: Book Review].—von Mises & Frank. (*Review*

Scient. Instr., Oct. 1944, Vol. 15, No. 10, pp. 254–255.) Reproduction by the photo-offset process.

945. "INTRODUCTION TO NON-LINEAR MECHANICS" [Book Review].—Kryloff & Bogoliuboff. (*Quart. Applied Math.* [Brown University], July 1943, Vol. 1, No. 2, pp. 192–193: translated from the Russian.) No. 11 of Princeton University "Annals of Mathematics Studies".

946. A METHOD FOR THE SOLUTION OF CERTAIN NON-LINEAR PROBLEMS IN LEAST SQUARES [and of Non-Linear Simultaneous Equations: the Method of "Damped Least Squares", and Its Advantages].—Levenberg. (*Quart. Applied Math.* [Brown University], July 1944, Vol. 2, No. 2, pp. 164–168.)

947. ON THE ASYMPTOTIC SOLUTION OF BOUNDARY-VALUE PROBLEMS FOR ORDINARY DIFFERENTIAL EQUATIONS CONTAINING A PARAMETER.—Wasow. (*Journ. of Math. & Phys.* [of M.I.T.], Nov. 1944, Vol. 23, No. 4, pp. 173–183.)

948. "MODERN OPERATIONAL MATHEMATICS IN ENGINEERING" [Book Review].—Churchill. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, p. 648.)

Companion to the book referred to in 2901 of 1941. "The subject is mainly the transient phenomena of electric currents, mechanical displacements, and heat transfer, all of major interest to the radio engineer . . ."

949. "THE SIMPLE CALCULATION OF ELECTRICAL TRANSIENTS" [Book Review].—Carter. (*See* 742.)

950. "MATHEMATICAL AND PHYSICAL PRINCIPLES OF ENGINEERING ANALYSIS" [Book Review].—Johnson. (*Proc. I.R.E.*, Sept. 1944, Vol. 32, No. 9, p. 574.)

951. ON A CLASS OF INTEGRO-DIFFERENTIAL EQUATIONS [and the "Generalised Fourier Series" as Their Solution], *and* DOUBLE FOURIER SERIES AND BOUNDARY-VALUE PROBLEMS.—Pitt: Green. (*Proc. Cambridge Phil. Soc.*, Oct. 1944, Vol. 40, Part 3, pp. 199–211: pp. 222–228.)

952. A NEW PHOTOELECTRIC METHOD FOR FOURIER SYNTHESIS AND ANALYSIS.—Fürth & Pringle. (*Phil. Mag.*, Oct. 1944, Vol. 35, No. 249, pp. 643–656.)

The method is proposed, and shown to work satisfactorily, "not because of any deficiency in the already existing methods but because it is based on principles which have apparently not been used for this purpose before, and therefore seems to be of some interest in itself; and also because one single instrument constructed on these principles can be used for both analysis and synthesis." The basic principle of the synthesiser is the production of a number of light beams, the intensity of each of which is made to vary in time according to a sine or cosine function with a frequency equal to an integer multiple of a fundamental frequency, the amplitudes of these oscillations being set so as to correspond to the given coefficients of a Fourier series. The time variation of the output of a photocell gives the synthesised function.

In all methods of Fourier analysis whose aim is to calculate not only the amplitudes but also the phases of the harmonic components, it is necessary to evaluate integrals of the products of two periodic functions over the fundamental period. Used as an analyser, therefore, the apparatus employs a second photocell and takes advantage of the multi-grid-valve property used in the "mixing" process in superheterodyne reception.

953. AN ELECTRICAL CIRCUIT FOR HARMONIC ANALYSIS AND OTHER CALCULATIONS [D.C. Circuit, Inexpensive & Simple to Construct, with Average Error less than 0.1% of Largest Quantity involved].—Rymer & Butler. (*Phil. Mag.*, Sept. 1944, Vol. 35, No. 248, pp. 606–616.)

Designed to evaluate quantities of the form $\Sigma p_n q_n$, where the q's are selected from a discrete set of numbers and the p's can each have any value between 0 and 1. "As an example of the versatility of an instrument of this type, it may be mentioned that we have had occasion to evaluate quantities of the form $\Sigma n a_n / \Sigma a_n$ . . ."

954. ON THE QUANTIZATION OF PROBABILITY [Correspondence on Goldsmith's Suggested Theory, 1726 of 1944].—Dunlap: Goldsmith. (*Phys. Review*, 1st/15th Aug. 1944, Vol. 66, No. 3/4, pp. 92–93.)

955. PROBABILITY METHOD APPLIED TO THE ANALYSIS OF RECRYSTALLISATION DATA.—Dunn. (*Phys. Review*, 1st/15th Oct. 1944, Vol. 66, No. 7/8, pp. 215–220.)

956. ON A CRITERION OF INDEPENDENCE [in the Theory of Probability].—Ville. (*Comptes Rendus* [Paris], 5th/28th April 1943, Vol. 216, No. 14/17, pp. 552–553.)

957. "ELEMENTARY STATISTICS" [Book Review].—Levy & Preidel. (*Wireless Engineer*, Jan. 1945, Vol. 22, No. 256, pp. 14–15.) "This excellent five shillingsworth . . ."

958. REFINED QUALITY CONTROL SPEEDS UP PRODUCTION: CONTROL CHART HELPS SPOT PROCESS TROUBLE, SAVES INSPECTION COST.—Gaillard. (*Elec. Communication*, No. 1, Vol. 22, 1944, pp. 3–10.)

959. HELPING THE WAR-MAIMED [Note on Sir Ian Fraser's Advertisement for a Technician to develop Bridge-Playing Device].—St. Dunstan's. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, p. 360.) *See* Advt. p. 31.

960. INVENTIVE PROBLEMS OF MILITARY INTEREST [Selection from a More Comprehensive List].—Nat. Inventors Council. (*Proc. I.R.E.*, Nov. 1944, Vol. 32, No. 11, pp. 714–715.) For previous lists *see* 288 & 3719 of 1944.

961. AIRCRAFT RADIO MAINTENANCE.—Trumbull. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 118–121.)

"Duties and required qualifications of each type of aircraft radio mechanic, and general discussion of maintenance procedures used by large commercial

air-lines to keep both ground and flying radio equipment in proper condition with minimum plane lay-over."

962. SCIENCE WORKS WITH THE ARMED FORCES [including " a Kind Word for Red Tape "].—Furer. (*Scient. Monthly*, Aug. 1944, Vol. 59, No. 2, pp. 130–132.) Rear-Admiral Furer is the Coordinator of Research & Development for the U.S. Navy.

963. FUTURE OF RADIO AND ELECTRONICS.—Beal. (*Proc. I.R.E.*, Oct. 1944, Vol. 32, No. 10, pp. 46A, 48A.) For previous predictions *see* 1989 of 1944.

964. POST-WAR REORGANISATION : AVIATION RADIO BEACONS.—Morse. (*See* 823.)

965. REORGANISING BROADCASTING [Suggestions for Post-War Broadcasting].—Boswell. (*See* 937.)

966. BOOKS : THE WAREHOUSE OF KNOWLEDGE [and the Seriousness of the Present Situation regarding Text-Books & Monographs].—Brightman. (*Nature*, 30th Sept. 1944, Vol. 154, No. 3909, p. 434.)

967. AID TO LIBRARIES IN WAR AREAS.—American Library Association. (*Review Scient. Instr.*, Sept. 1944, Vol. 15, No. 9, p. 237.)

968. NEW MAGAZINE FOR LATIN AMERICA ISSUED [Note on *El Ingeniero Westinghouse*].—Westinghouse. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, p. 350.)

969. " ABBREVS : A DICTIONARY OF ABBREVIATIONS " [covering Literary, Scientific, & Industrial Fields : Book Review].—Stephenson. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, p. 354.)

970. COORDINATION OF ELECTRICAL GRAPHICAL SYMBOLS [Recommended Basic Symbols], *and* CIRCUIT SYMBOLS STANDARDISED [Compromise reached at March Meeting].—American Standards Association. (*Review Scient. Instr.*, Aug. 1944, Vol. 15, No. 8, p. 217 : *Electronics*, July 1944, Vol. 17, No. 7, pp. 92–93.) *See* also Cockrell, 765, above, and 4054 of 1944.

971. TRIMETRIC DRAWINGS—AN AID TO PRODUCTION [4052 of 1944 & Back References : Recent Devices (Axonograph, etc.)].—Glenn L. Martin Company. (*Elec. Engineering*, Oct. 1944, Vol. 63, No. 10, p. 360.)

972. BUYERS' GUIDE : A 1944/5 DIRECTORY OF ELECTRONIC AND ALLIED PRODUCTS.—(*Electronics*, June 1944, Vol. 17, No. 6, pp. D1–D48.)

973. " RADIO WAVES AND THE IONOSPHERE " [Book Review].—Bennington. (*See* 710.)

974. " HOW TO PASS RADIO LICENCE EXAMINATIONS " [Book Review].—Drew. (*Proc. I.R.E.*, Sept. 1944, Vol. 32, No. 9, p. 574.)

975. " FOUNDATIONS OF WIRELESS : FOURTH EDITION " [Book Review].—Scroggie. (*Proc. I.R.E.*, Sept. 1944, Vol. 32, No. 9, p. 574.) An English review was referred to in 2399 of 1944.

976. " FUNDAMENTALS OF RADIO COMMUNICATIONS " [Book Review].—Frey. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 262–263.)

977. " ELECTRICAL ESSENTIALS OF RADIO ", *and* " SHOP JOB SHEETS IN RADIO, BOOK I—FUNDAMENTALS " [Book Reviews].—Slurzberg & Osterheld : Auble. (*Proc. I.R.E.*, Sept. 1944, Vol. 32, No. 9, pp. 574–575 : p. 575.) For a review of " Book II—Service Problems " of the " Job Sheets " *see* October issue, No. 10, p. 648.

978. INTERFERENCE FROM RADIO-FREQUENCY HEATERS : SUGGESTIONS FOR CONTROL.—Youle. (*Wireless World*, Dec. 1944, Vol. 50, No. 12, pp. 374–375.) For a leading article *see* p. 353.

979. SURFACE HARDENING OF METALS [Some Techniques & Results].—Gillespie. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 102–105 and 188..196.) From the R.C.A. Victor Division.

980. THE USE OF RADIO-FREQUENCIES TO OBTAIN HIGH POWER CONCENTRATIONS FOR INDUSTRIAL HEATING APPLICATIONS, *and* NEW METHODS AND TECHNIQUES IN HIGH-FREQUENCY HEATING.—Roberds : Mittlemann. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 281 : p. 281 : summaries of Nat. Electronics Conference papers.)

981. SURFACE HEATING BY INDUCTION, *and* INDUCTION HEATING : THE SELECTION OF FREQUENCY.—Storm : Stansel. (*Elec. Engineering*, Oct. 1944, Vol. 63, No. 10, Transactions pp. 749–755 : pp. 755–759.)

(i) Previous analysis has been by means of partial differential equations whose solutions are Bessel functions. " It is the object of this paper to analyse the induction-heating effect by using concepts commonly applied to a.c. engineering without involving differential equations. It was found that ordinary vector diagrams lead to quantitative expressions for the penetration of the magnetic field into the charge, for the distribution of eddy currents and generated heat, as well as for the impedance of the loaded inductor."

(ii) Deals with " the relation of frequency and kilovolt-ampere capacity as the basis for the selection of the frequency for a given heating service."

982. THE OBTAINING OF EXTREMELY HIGH TEMPERATURES [Higher than Those given by Condenser Discharge by Thin Wires, and Other Methods : Compression of Mercury Vapour by Shock Wave produced by Bullet].—Zeldovich & Leipunsky. (*Journ. of Phys.* [of USSR], No. 5, Vol. 7, 1943, p. 245 : in English.)

983. ELECTRONIC THERMOMETER [Construction, Circuits, Direct Use as Control, Great Advantages].—Weiller & Blatz. (*Electronics*. July 1944, Vol. 17, No. 7, pp. 138–139 and 362, 363.) *See* also 694 of February.

984. A Circuit for measuring Temperatures by a Resistance Thermometer.—Guillien. (*See* 874.)

985. Studying Thermal Behaviour of Houses [Thyratron/Pentode Control for Electrical Model of House reduces 24-Hour Heating Cycle to 1/60th Second].—Linvill & Hess. (*Electronics*, June 1944, Vol. 17, No. 6, pp. 117–119 and 362.)

986. Remark on Kirschstein's Paper "A Method for the Exact Regulation of Fixed Rotational Speeds of an Axle."—Boedeker: Kirschstein. (*See* 861.)

987. An Electronic Tachometer, Accelerometer, and Vibrometer [primarily for Rapid Testing of Gyroscope Rotors: with Piezoelectric & Electrostatic Pick-Ups].—Conn, Ltd. (*Electronics*, June 1944, Vol. 17, No. 6, pp. 100–104 and 310, 312.)

988. Aircraft Electronic Applications.—Upton. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 280.)

989. Aircraft-Engine Torque Instruments [Survey, including the Possibilities of the Magnetic-Skin-Effect or Magnetostriction Type: Details of a New Magnetic-Coupled Torquemeter].—Godsey & Langer. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, Transactions pp. 686–690.)

990. Magnesyn Remote Indication [a Bendix Aviation Corporation Development].—Childs. (*Elec. Engineering*, Sept. 1944, Vol. 63, No. 9, Transactions pp. 679–682.)

991. The Development of an Automatic Electric Balance for Research on Aerodynamic Stability [and the Attainment of Stability of Balance by the Inclusion of a Phase-Shifting Network in the Photocell-Amplifier Circuit].—Bratt & Wight. (*Phil. Mag.*, Sept. 1944, Vol. 35, No. 248, pp. 588–600.)

992. Electronic Protective Systems [Survey of Sound-Actuated, Capacitance-Change, & Photoelectric Alarm Systems].—Lindsay. (*Elec. Engineering*, Oct. 1944, Vol. 63, No. 10, pp. 367–374.)

993. Detecting Fires at Sea [by Smoke-Detecting Photoelectric Unit: Automatic System].—(*Electronics*, July 1944, Vol. 17, No. 7, p. 125.) An addition to the Rich system for detecting smoke by sight and smell.

994. The Measurement of the Correlations in Atmospheric Turbulence [by the Photoelectric Anemometer with Very Low Inertia]. Faillettaz. (*See* 727.)

995. Accurate Sorting of Coloured Objects [Addition of Automatic Operation (by Photoelectric Unit) to Cathode-Ray Oscilloscope in Production-Line Sorting: Apparatus for Automatic Sorting of Coloured Tiles emerging from Kilns on Conveyor-Belt].—Antes. (*Electronics*, June 1944, Vol. 17, No. 6, pp. 114–116.)

996. "Colorimetric Methods for the Determination of Traces of Metals" [Book Review].—Sandell. (*Phil. Mag.*, Sept. 1944, Vol. 35, No. 248, pp. 641–642.)

997. Applications of the Band Spectra of Molecules [including the Investigation of Vacuum Tubes for the Origin of Unwanted Residual Gases].—Pearse. (*Nature*, 26th Aug. 1944, Vol. 154, No. 3904, p. 279.) In an account of an Institute of Physics conference on the applications of spectroscopy to industrial and other problems.

998. Reducing Electrical Interference from Spectrographic Spark Source.—Landen. (*Journ. Opt. Soc. Am.*, Sept. 1944, Vol. 34, No. 9, p. 532.)

999. Studies on Double Refraction of Flow: I—An Apparatus for the Study of Double Refraction of Flow at High Velocity Gradients [for Study of Liquids containing Elongated Molecules].—Edsall & others. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, pp. 243–252.)

1000. Doppler Effect in a Refractive Medium.—Frank. (*See* 729.)

1001. Natural Limits of measuring Radiation with a Bolometer.—Milatz & van der Velden. (*Physica*, June 1943, Vol. 10, p. 369 onwards.) A 12-page paper, referred to in *Review Scient. Instr.*, Sept. 1944.

1002. Field Emission applied to Ultra-Speed X-Ray Technique [where Electron Currents of 2000–3000 Amperes are required].—Slack. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 281: summary of Nat. Electronics Conference paper.) "Possible applications of this intense electron source to other electronic devices will be discussed."

1003. Industrial Fluoroscopy of Light Materials.—Smith. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 281: summary of Nat. Electronics Conference paper.)

1004. Photoelectric Plethysmograph [for Measuring the State of Fullness of Blood Vessels: Photoelectric Device clipped to Ear: "a Unique Direct-Coupled Push-Pull Amplifier" (with Many Other Applications) driving an Inkwriter].—Gilson. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 116–117 and 318, 320.) For a device for measuring the degree of oxygen saturation *see* Millikan, 954 of 1943.

1005. Direct-Recording Electrocardiograph [Inkless, giving Instantaneous Readings: eliminating Photographic Procedures].—Electro-Physical Laboratories. (*Review Scient. Instr.*, Oct. 1944, Vol. 15, No. 10, p. 274.)

1006. Effects of Electric Shock [Discussion of the Three Major Causes of Accidental Electrocution: with Electrocardiograms, Literature References, & List of Practical Precautions].—Poehler. (*Electronics*, July 1944, Vol. 17, No. 7, pp. 140–142 and 250..254.)